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Self-organizing Networks and GIS Tools Cases of Use for the Study of Trading Cooperation (1400-1800)

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(coords.)

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Introduction

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The collected essays comprised in this work are the result of the first years of research by the scientists who make up the DynCoopNet work team.[1] In the framework of the EUROCORES Programme as part of the TECT call – The Evolution of Cooperation and Trading – of the European Science Foundation, this was one of five projects approved by this ambitious, interdisciplinary scientific programme. The aim of this programme has been the study of the emergence of and evolutionary processes of exchange and cooperation that occur in nature, including human societies.[2] This programme was based on a series of common ideas. The phenomenon

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[1]	The Collaborative Research project "Dynamic complexity of Self-Based Organized Networks of the First Global Age", is carried out within the framework of the EUROCORES Programme of the European Science Foundation, TECT call: "The Evolution of cooperation and Trading", Reference: (06-TECT- FP004), and co-funded by the Spanish Ministry of Science and innovation, by the National Science Foundation in United States (NSF) and by the Portuguese Foundation for Science and Technology (FCT).

[2]	Richardson, P. J. & Boyd, R. *Not by genes alone: How culture transformed human evolution*. (Chicago, University of Chicago Press, 2005). All conclusions about this programme have been highlighted by Ronald Noe in the Introduction to *The Evolution of cooperation and Trading (TECT). Final Report*, edited by Barry Dixon, Eva Hoogland and Claire Rustat-Flinton (Strasbourg, European Science Foundation, 2011): 3-4.

of cooperation essentially has, at various organisational levels, the same roots and raison d'être in all evolutionary processes whether genetic or historic-cultural. Scientists know that these processes emerge in various social contexts or ecosystems, where bacteria or human societies in multinational alliances have been elements involved. However, in most cases, Science is still unable to determine and define cooperation and why it takes place. Despite a relative lack of research, the study of cooperation has had numerous, convergent developments in various fields, such as Economics, Biology and Sociology. It can be said, in practice, that there is a common theory which explains biological and cultural evolution. This theory highlights features of interactions between agents or entities, which have developed even more in relation to economic behaviour than Social and Human Sciences. In this case, our project has been greatly enriched by an excellent bibliographical base.[3] Generally speaking, theories relating to the emergence of cooperation mechanisms have been applied in various fields, from Neuroscience (especially with regards to Cognitive Theory) to Economic History (Game Theory).[4]

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3   Ballard, R. "Coalitions of reciprocity and the maintenance of financial integrity within informal value transmission systems: The operational dynamics of contemporary hawala networks", *Journal of Banking Regulation* 6 (2005), (4), pp.319-352; Dendrinos, D. & Sonis, M. *Chaos and socio-spatial dynamics. Applied Mathematical Sciences,* vol. 86. (New York, Berlin, Heidelberg, London, Paris, Tokyo, and Hong Kong: Springer-Verlag, 1990); Faust, K. & Skvoretz, J. "Comparing networks across space and time, size and species", *Sociological Methodology,* (2002), 32, pp. 267-299; Rosser, J. B. Jr. & Rosser, J. B. *From catastrophe to chaos: A general theory of economic discontinuities.* Vol. I. 2nd (ed. Berlin & New York: Springer-Verlag, 2006 [2000]); Sonis, M. & Hewings, G. J. D. Economic complexity as network complication: Multiregional input-output structural path analysis. *The Annals of Regional Science*, 32, pp. 407-436; White, D. R. (2003). Eds., *Networks and complexity: Converging streams of research. Complexity*, (1998), 8 (1), p. 14.

4   Broadly explained in: Owens, J. B., "Dynamic Complexity of Cooperation-Based Self-Organising Networks in the First Global Age (DynCoopNet)." In Ronald Noe, Rüdiger Klein, Julia Bowman, and Claire Rustat-Flinton (eds.), *The Evolution of Cooperation and Trading (TECT)* (Strasbourg, FR: European Science Foundation, 2008): 23-35 [The complete, illustrated booklet is available at the URL www.esf.org/activities/eurocores/programmes/tect.html.]; Owens, J. B., "Toward a geographically-integrated, connected world history: Employing geographic information systems (GIS)." *History Compass*, 5, 6 (October 2007): 2014-2040, 10.1111/j.1478-0542.2007.00476.x.

Within this broad research framework, "Dynamic Cooperation Networks" is an interdisciplinary project with historians, mathematicians, cartographers and GIS engineers from the USA, Portugal, Spain, Germany, the Netherlands, India, Sweden, Mozambique and other countries. This collaborative research team has focused on how cooperation was significant within self-organising networks in the so-called First Global Age (1400-1800). Therefore, this research project addressed an important collective study about historical conditions for emerging elements of cooperation in the context of a complex dynamic system that characterises World History from around 1500 AD. Without doubt, several studies have brought to light a new theoretical and methodological background for those cooperation mechanisms which led to the establishment of new forms of social networks between merchants and financiers. Taking advantage of these social structures, commerce and finances could be shaped through time and space from the 16th century onwards, bringing together merchant nations and people as well. In this respect, this special issue offers different historical research on this topic. However, it includes important news about how our goals as historians could be achieved: we try to show how databases and GIS can be useful for historical research. So, contributors offer results for a deeper understanding of commerce during First Global Age and, with this, they explain how they have made use of new technologies to reach their objectives. GIS has been drawn on as an integration device for information, as a visualization tool, where data on world commerce has been collected. This GIS experience has created an integrated and shared database about means and procedures of cooperation during the First Global Age. Other databases help to

combine information about agents from different points of view, namely \agents for commercial, finance, politic, ideology, society and so on. Databases also include material about means of cooperation, sailing, maritime trade, routes, ports and other essential entities for historical research. Spatial and temporal movement is expected to be essential in this project, as migratory shifts constitute a key issue for understanding how global phenomena have emerged. The formation of societies and the interconnection of social networks during the centuries of the first global age is a field of study which, besides being an ongoing line of research in the area of Social Sciences and Humanities, poses a challenge to the historian as a social scientist and an expert in the Domain.[5] Analysis of the historical evolution of social processes is, moreover, a challenge to the application of new innovative methodological perspectives. In order to approach more complex historical knowledge, Historians and Scientists need to refer to languages and methods related to analysis of human behaviour from an interdisciplinary perspective. This project came to fruition as a result of a long reflection process, analysing the historical evolution of a series of historical processes that took place due to the emergence of new forms of human behaviour. These new forms took place over a long period of time (1500-1800) and in a transnational geographic context, where new types of social environments were created through close contact with other parts of the world. Jack

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5   Fujita, M., Krugman, P. & Venables, A. J. *The spatial economy: cities, regions, and international trade.* (Cambridge, London: MIT Press; 1999); (Henrich J. 2004).. Cultural group selection, coevolutionary processes and large-scale cooperation. *Journal of Economic Behavior and Organization* 53: 3-35; Hewings, G. J. D., Sonis, M. & Boyce, D. (Eds.). *Trade, networks, and hierarchies: Integrated approaches to modeling regional and interregional economies.* (Heidelberg, New York: Springer Verlag, 2001); Krugman, P. (1996). *The self-organizing economy. Mitsui Lectures in Economics.* (Cambridge, Oxford: Blackwell Publishers, 1996); and Crespo Solana, Ana, ed. *Comunidades transnacionales. Colonias de mercaderes extranjeros en el mundo atlántico, 1500-1800,* (Madrid: Doce Calles, 2010).

Owens defends the idea of establishing a theoretical model on the emergence of new forms of cooperation in the context of a dynamic complex system in which networks worked, as well as revealing the mechanisms that allowed the various types of agents to establish and sustain a cohesion that often spanned long distances within a very wide geo-historical space. Such analyses would be greatly enriched by the utilisation of innovative technology to improve the ability to visualize and analyse – Geographic Information Systems or GIS (Owens & Wachowicz). As historians we have devoted our time and efforts to defining this First Global Age. This space – the space we study – has been defined by the theorists of the World System in different ways, and these theorists have contributed their perspectives of analysis towards the creation of designations such as World System or Atlantic System. Generally speaking, this space is in fact a global system where interactions occurred; thus we have drawn up, from World Connected History,[6] a theoretical-methodological framework for this sense of the term "World Connected History". The consequence of European expansion between the 16th and 18th century was the emergence of merchant societies – social environments – centred around trade activities (Alonso García, Picazo Muntaner and Mukherjee). This was the beginning of a process that had precedents in the Ancient World but which had not yet reached the level that was attained from the 15th century onwards. This process led to the integration of a global network that was clearly characterised by the complexity of its interconnection. At this stage, cooperation and competition are two issues that are close together and not entirely

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6   Frank, A. G. ReORIENT: *Global economy in the Asian age.* (Berkeley, Los Angeles: University of California Press, 1998); Ringrose, D. R. *Expansion and global interaction, 1200-1700* (New York: Addison Wesley Longman, 2001).

unrelated. In the transnational empire of the Iberian monarchies (Portugal and Spain), its complex economic network was sustained by the trading and financial services provided by all its agents. The merchant communities of various nationalities played a crucial role in this respect as they formed the financial basis of the empire as well as managing Spain's prosperous foreign trade. Intercontinental trade increased thanks to the ambition and aspirations of the merchants who, through diasporas, settled in various cities and organised themselves into institutions and networks. This process sustained homogeneous trading practices during the so-called commercial Revolution. The empirical data analysed in the case of the Portuguese Empire, even if taken only as samples, is very enlightening in terms of the indisputable presence of Portuguese in the Spanish Indies, as it is true evidence of informal and self-organised Portuguese international networks operating in that part of the Early Modern colonial world. In the examples of Polonia and Barrios, a sort of global interaction is described between different spaces of Iberian Monarchies. This kind of widespread interaction was not restricted just to the Americas but spread over the whole of Europe, with Medina del Campo fairs, Madrid, Lisbon, Seville, Antwerp (and later on, Amsterdam), Paris, Besançon, and Hamburg, cities where capital flowed. These networks frequently involved business that connected, once more, Portugese and Spanish overseas trade and their interests in international financial circuits. The conclusions of this work demonstrate how this theoretical and methodological context is useful when studying Modern History from a truly interdisciplinary perspective, especially given that the First Global Age was notoriously characterised by the emergence of processes of formation and development of specialised

merchant societies that made trade and seafaring their main ways of life and thus provided the younger generations with new opportunities for growth. This process also affected the various societies in outside of Europe.[7] It is important to analyse these communities by looking at their network connections following merchant migration. We should also focus on the network connections of people that lived on their seafaring, financial or manufacturing skills happened within a number of diasporas which occurred around interrelated historical junctures and migrations (Crespo Solana).

Papers devoted to GIS technologies show how GIS is being applied to different fields in which the dynamic modelling of the phenomena requires both the temporal component and the spatial context in which they develop. The temporal variable implies taking into account time scales, granularity and the cyclical behaviour of certain events. It makes the task somewhat more complex than simply adding columns to the database to indicate the beginning and end of the event (Urrutia Zambrana,García Rodríguez and Bernabé Poveda). In other cases, the extended design of a GIS-based set of tools to analyse spatio-temporal data in order to enable researchers recognising patterns or behaviour activities over time is also generally explained. To design the prototype and its implementation in a GIS, we used an extensive online database on trans-Atlantic slave trade routes between the 16th and 19th century. This database contains approximately 35,000 trips identifying more than 270 aspects of each, allowing for analysis of the space-time behaviour of these ships and presents different dynamic visualisations of what happened.[8] This design is considered a starting point for developing other geo-

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7   Curtin, Ph. D, *Cross-cultural Trade in World History,* (Cambridge University Press, 1984)
8   The Database is available in: http://www.slavevoyages.org/tast/database/index.faces.

information tools to be applied in studies of merchant networks and trading cooperation (Pérez Asensio, del Bosque, Maestre, Sanchez-Crespo Camacho and Crespo Solana).[9]

Spatial Data Infrastructures have become a methodological and technological benchmark, enabling distributed access to historical-cartographic archives. It is essential, however, to offer enhanced virtual tools which imitate the current processes and methodologies carried out by librarians, historians and academics in the existing map libraries around the world. As a generic framework for managing, querying and accessing distributed geo-referenced resources, support tools to provide enriched browsing and dynamical querying methods based on SDI foundations and the DIGMAP engine, which enables access to georeferenced historical-cartographical archives have been designed and developed. In this way, it is possible to achieve the integration of virtual map rooms and SDI technologies bringing support to researchers within the historical and social domains (Siabato, Bernabé Poveda and Fernández-Wyttenbach). The purpose of this work is to make an indepth study of the incorporation of the temporal component in a GIS from a linguistic perspective, specifically from a semantic annotation perspective. A methodology is proposed for integration of natural language temporal expressions using the Natural Language Processing (NLP). Text documents normally contain temporal expressions letting us know when an event occurred, how long certain events lasted, etc. Understanding the semantic of these expressions, even modelling it in a database for its incorporation in a GIS (Geographic Information System), is an area of interest in many fields, particularly in History. In this

paper we have used TimeML, a program which enables recognition and normalisation of natural language temporal expressions, for integration of these expressions into a geo-database with application to a GIS. In addition, systematic analysis of these natural language expressions is presented with the aim of extending GIS capabilities through introduction of semantics and natural language, adapting text documents for the dynamic representation of information in a GIS (Guerrero Nieto, Urrutia Zambrana, Bernabé Poveda and García Rodríguez).

Atlantic and global history studies have recently benefited from the spatial turn, a theory which re-assesses spatio-temporal analyses.[10] In fact, time and space do truly represent a continuous return of Atlantic historiography, which includes global, cisatlantic and comparative geographic analyses and encompasses the study of agents and networks, factors and regions, from a spatial perspective. The goal of the last paper is to present a set of general analytical tools that are deemed to help researchers of maritime history to discover significant elements of the structure of historical shipping that would otherwise remain invisible. It is hoped that these tools will help researchers to generate new hypotheses (Scheltjens). The tools in this paper are based on existing methods for exploratory data analysis. Their theoretical basis is evolutionary; the tools are constructed in such a way that they allow us to discern and interpret processes of origination, adoption and retention.

In summary, this special issue proposes new innovative ways of trandisciplinary work for Social Scientists and Historians, in

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10   A study about how spatial turn can be useful for historians, M. Middell and K. Naumann, "Global History and the Spatial Turn: From the Impact Areas Studies to Study of Critical Junctures of Globalization", *Journal of Global History*, nº 5 (2010), pp. 149-170.

order to take advantage of new technologies and share information. Contributors present their conclusions on merchant and financial cooperation during the First Global Age and explain how GIS and databases can be used. The DynCoopNet project presents a real and interdisciplinary way of integrating historical, economic, cartographic information, social networks tools and mathematical models. Analysing thousands and thousands of pieces of data through computer programs involves large groups of researchers. In other words, this special issue is a proposal for unknown levels of cooperation between scientists in different fields. As such, we talk about the past but, at the same time, we are thinking about the future.

Dynamic Complexity of Cooperation-Based Self-Organizing CommercialNetworks in the First Global Age(DynCoopNet): What's in a name?[1]

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Introduction

Because we have told in other places the story of the creation of the DynCoopNet Project and the geographically-integrated history paradigm underlying the original funding proposal,[2] this chapter will be dedicated to two related tasks. First, I will undertake a close examination of the concepts embedded in its long title. Second, I will explain how they fit together as a framework for the interactions of researchers drawn from a variety of disciplines to foster the emergence of new scientific ideas, which go beyond the

2   "What Historians Want from GIS," *ArcNews* 29, no. 2 (2007): 4-6, and http://www.esri.com/news/arcnews/summer07articles/what-historians-want.html (accessed on May 10, 2010); article reprinted in *GIS Best Practices: Essays on Geography and GIS* (Redlands, California: ESRI, 2008), 35-46, and in *GIS Best Practices: Social Sciences* (Redlands, California: ESRI, 2009), 35-45; "Toward a Geographically-Integrated, Connected World History: Employing Geographic Information Systems (GIS)," *History Compass* 5, no. 6 (2007): 2014-2040; doi: 10.1111/j.1478-0542.2007.00476.x; "A Multi-national, Multi-disciplinary Study of Trade Networks and the Domains of Iberian Monarchies during the First Global Age, 1400-1800," *Society for Spanish and Portuguese Historical Studies*: Bulletin 33, no. 2 (2008): 23-30; "What kind of system is it? The DynCoopNet Project as a Tribute to Andre Gunder Frank (1929-2005)," in *Networks in the First Global Age, 1400-1800,* ed. Rila Mukherjee (New Delhi: Primus Book, 2011, 3-9).

normal advances characteristic of work within a single discipline. By providing a concise, clear statement of these matters, I intend to provide a foundation for the further funding proposals of my DynCoopNet colleagues and others to advance the promising research direction we have established. Moreover, all other successful projects in the grant competition contain one or more researchers who knew about the program from its presentation in January 2005, but I only learned about it when I saw the call for proposal five weeks before the preliminary, outline proposal was due in June 2006. In this too-limited time period, we had to draft a proposal and recruit participating researchers from a variety of disciplines in sixteen countries on five continents. Therefore, this chapter affords me the opportunity to elaborate aspects of DynCoopNet project which were not clear at the beginning of this investigation.

Cooperation

The DynCoopNet Project began its life as a response to a call for proposals for the European Science Foundation research program entitled "The Evolution of Cooperation and Trading" (TECT).[3] As the original call made clear,[4] the topic possesses a vital contemporary interest. In 1968, noted biologist Garrett Hardin (1915-2003) chilled readers with a vision of a world in which hu-

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3   TECT home page: http://www.esf.org/activities/eurocores/running-programmes/tect.html (accessed on May 12, 2010).
4   http://www.esf.org/index.php?eID=tx_nawsecuredl&u=0&file=fileadmin/be_user/activities/ EUROCORES/TECT/TECT%20Call%2010.04.06.pdf&t=1273778972&hash=de6b17bdb74671ab8d3bc25 a6a8e19d4 (accessed on May 12, 2010).

mans failed to cooperate. "The Tragedy of the Commons"[5] used the master metaphor of a village's common-use grazing land on which, in the absence of cooperation for sustainability, each villager will graze as many animals as possible, eventually destroying a vital resource. Hardin's piece caused special concern because only four years before, evolutionary biologist William D. Hamilton (1936-2000) had demonstrated that, in theoretical terms, cooperation would always be destroyed by cheaters, defectors, and free-riders.[6] Such dramatic assertions of humans' tendency to destroy, rather than sustain, natural resources on which their lives depend initiated multiple research streams of considerable richness. As a sign of the importance given to this work, the Nobel committee for economics presented its 2009 prize (shared) to political scientist Elinor Ostrom (b. 1933), largely on the basis of her work on the governance of the "commons".[7]

I felt that I could assemble a multidisciplinary, multinational team, which could address the TECT call in a novel way. I had been struck in my research by the extraordinarily high levels of cooperation among those involved in the commercial networks of the First Global Age, 1400- 1800, in situations that provided little possibility for coercion of participant behavior. Much economic activity entailed clandestine relationships, which did not permit participants the easy use of the weak institutions that were available to seek redress from cheaters. Furthermore, the First Global Age constituted a different system from that of our time, offering to

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5   Garrett Hardin, "The Tragedy of the Commons," *Science* 162 (1968): 1243–1244.
6   William D. Hamilton, "The Genetical Evolution of Social Behaviour. I & II," *Journal of Evolutionary Biology* 7 (1964): 1–52.
7   For example, Elinor Ostrom, *Governing the Commons: The Evolution of Institutions for Collective Action* (Cambridge, UK, and New York: Cambridge University Press, 1990).

researchers the possibility of examining cooperation in the context of earlier institutional and personal relationships and of unfamiliar values and perspectives of the world. As Joseph R. Levenson (1920-1969) showed, following Alfred North Whitehead (1861-1947), a different system alters even the meaning of a seemingly familiar entity because relationships determine meaning rather than some essence possessed by an entity itself.[8] Finally, historians make frequent recourse to narrative explanations, and because narrative knowledge constitutes a unique and valuable form of knowledge[9] seldom employed in cooperation research, a project that included historians would make a substantial and innovative contribution to the TECT program.[10] In a recent review of cooperation research,[11]

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8   Joseph R. Levenson, *Confucian China and its Modern Fate*: *A Trilogy* (Berkeley and Los Angeles: University of California Press, 1968); Alfred North Whitehead, *Process and Reality: An Essay in Cosmology,* Gifford Lectures Delivered in the University of Edinburgh During the Session 1927-28 (London and New York: Macmillan, 1929). For a discussion of Levenson's work and its importance for research in world history, see Owens, "Toward a Geographically-Integrated, Connected World History."

9   Harlene Anderson and Harold A. Goolishian, Human Systems as Linguistic Systems: Preliminary and Evolving Ideas about the Implications for Clinical Theory, *Family Process* 27 (1988): 371-393.; Jerome S. Bruner, *Actual Minds, Possible Worlds* (Cambridge, MA: Harvard University Press, 1985); Clifford Geertz, *The Interpretation of Cultures* (New York, NY: Basic Books, 1973); J. H. Hexter, *The History Primer* (New York and London: Basic Books, 1971); Kathryn M. Hunter, *Doctors' Stories: The Narrative Structure of Medical Knowledge* (Princeton, NJ: Princeton University Press, 1991); John Launer, *Narrative-based Primary Care: A Practical Guide* (Oxford, UK: Radcliffe Medical Press, 2002).

10   For indications of the state of cooperation research at the time of the DynCoopNet proposal, see Karen S. Cook, Russell Hardin, and Margaret Levi, *Cooperation without trust?* (New York: Russell Sage Foundation, 2005); Joseph Henrich *et al.*, "Overview and Synthesis," in *Foundations of Human Sociality: Economic Experiments and Ethnographic Evidence from Fifteen Small-Scale Societies,* eds. Joseph Henrich *et al.* (Oxford, UK, and New York: Oxford University Press, 2004); Laurent Lehman and Laurent Keller, "The Evolution of Cooperation and Altruism – a General Framework and a Classification of Models," *Journal of Evolutionary Biology* 19 (2006): 1365-1376; Martin A. Nowak, "Five Rules for the Evolution of Cooperation," *Science* 314 (2006): 1560-3.Joel L. Sachs, Ulrich G. Mueller, Thomas P. Wilcox, and James J. Bull, "The Evolution of Cooperation," *Quarterly Review of Biology* 79 (2004): 135–160; Raimo Tuomela, *Cooperation: A Philosophical Study* (Dordrecht and Boston: Kluwer Academic Publishers, 2000); Stuart A. West, Ashleigh S. Griffin, and Andy Gardner, "Social Semantics: Altruism, Cooperation, Mutualism, Strong Reciprocity and Group Selection," *Journal of Evolutionary Biology* 20 (2007): 415–432; Stuart A. West, Ashleigh S. Griffin, and Andy Gardner, "Evolutionary Explanations for Cooperation: Review," Current Biology 17 (August 2007): R661-R672.

11   Laurent Lehmann, Kevin R. Foster, Elhanan Borenstein, and Marcus W. Feldman, "Social and

mostly done by evolutionary biologists and economists interested in game theory, the authors account for the inadequacy of results by pointing to the failure to deal with the role of individual intentions. Although the article's authors propose designing new games to test the impact of individual intentions, historians provide a great deal of information about this factor, which will permit researchers who focus on the First Global Age to offer innovative explanations for the high levels of cooperation during this four-century period in the face of a relative absence of coercion.

Geographically-Integrated History

DynCoopNet proposed to deal with the problem presented by the presence of so much cooperation through the application of geographically-integrated history. As a research and teaching discipline, we founded geographically-integrated history on the idea that the understanding of historical processes requires an integration of place, space, and time and accomplishing this integration poses a challenge, which can be met with modern information management, especially geographic information systems (GIS), and visualization techniques. The underlying transformative geographically-integrated history research paradigm posits that:

1) the history of any place is shaped by the way the place is connected to other places and the changes in these connections over time;[12]

Individual Learning of Helping in Humans and Other Species," *Trends in Ecology and Evolution* 23, no. 12 (2008): 664-671.

12   Harm J. De Blij, *The Power of Place: Geography, Destiny, and Globalization's Rough Landscape* (Oxford, UK: Oxford University Press, 2009); Organization of American Historians, *LaPietra Report: A Report to the Profession* (2000), http://www.oah.org/activities/lapietra/final.html (accessed on May 14,

2) historical periods are complex, dynamic, nonlinear systems, which are spatially large, and in more recent centuries, global in extension, and which sometimes become unstable, leading to a phase transition, bifurcation, and the organization of new systems;[13]

3) And within such systems, people and places are connected by self-organizing networks, which are the sources of innovation and the emergence of new forms.[14]

Because the emergence of new forms often moves research from a topic within one discipline to a topic within another, our attempt to understand the past must be interdisciplinary and collaborative. We created Geographically-Integrated History as a "discipline" to encompass those with the will and imagination to cross established disciplinary boundaries in an effort to move from data (including tabular data, images, historic cartography, musical composition, etc.) to enhanced knowledge.

2010); Owens, "Toward a Geographically-Integrated, Connected World History"; Sanjay Subrahmanyam, *Explorations in Connected History* (Delhi, IN: Oxford University Press, 2004); Sanjay Subrahmanyam, "Holding the World in Balance: The Connected Histories of the Iberian Overseas Empires, 1500-1640, *American Historical Review* 112, no. 5 (December 2007): 1359-1385.

13   On such systems, see Tönu Puu, *Attractors, Bifurcations and Chaos: Non-linear Phenomena in Economics* (2nd ed., Berlin and Heidelberg, DE: Springer-Verlag, 2003); Tönu Puu, *Arts, Sciences, Economics: A Historical Safari* (Berlin and Heidelberg, DE: Springer-Verlag, 2006); J. Barkely Rosser, Jr., *From Catastrophe to Chaos: A General Theory of Economic Discontinuities*, vol. I. (2nd ed.; Boston, MA: Kluwer Academic, 2000); Thierry Vialar, *Complex and Chaotic Nonlinear Dynamics: Advances in Economics and Finance, Mathematics and Statistics* (Berlin et al: Springer, 2009).

14   Ronald S. Burt, "Structural Holes and Good Ideas," *American Journal of Sociology* 110 (2004): 349- 399; Eiko Ikegami, Eiko, "A Sociological Theory of Publics: Identity and Culture as Emergent Properties in Networks," *Social Research* 67 (2000): 989-1029; Eiko Ikegami, *Bonds of Civility: Aesthetic Networks and the Political Origins of Japanese Culture* (Cambridge, UK, & New York: Cambridge University Press, 2005); Mark Newman et al, *The Structure and Dynamics of Networks* (Princeton, NJ: Princeton University Press, 2006).

Ontology: What reality is like

The DynCoopNet enterprise, which entails the use of computer-driven information management and visualization software, demands that researchers carefully formulate an ontology that expresses the nature of reality and the relations among entities. Because a formal ontology would require a precision that depends on research DynCoopNet is designed to accomplish, and which may be impossible to achieve when dealing with a complex human system,[15] I provide here only an outline of the project's fundamental concepts and how they are connected within the project. Through the linking of concepts drawn from diverse disciplines, DynCoopNet provides a context for multidisciplinary collaboration. From this perspective we are deriving conceptual and computational tools for dealing with the qualitative information so often provided by historians and historical social scientists.

Complex, Dynamic, Nonliner Systems

DynCoopNet frames the First Global Age as a complex, dynamic, nonlinear system. Note that we offer this model as a

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15   On the problems of developing ontologies, especially ones that might actually be of use when dealing with human systems, see Thomas Hofweber, "Logic and Ontology," *Stanford Encyclopedia of Philosophy* (2004), http://plato.stanford.edu/entries/logic-ontology/ (accessed May 15, 2010); Wolfgang Künne, *Conceptions of Truth* (Oxford, UK: Oxford University Press, 2003); Henry Laycock, *Words without Objects: Semantics, Ontology, and Logic for Non-singularity* (Oxford, UK: Clarendon Press, 2006). On the issue of mathematical precision and human systems, I like the view of Herbert Gintis: "In fact, physicists generally judge models according to their ability to account for the facts, not their mathematical rigor. Physicists generally believe that rigor is the enemy of creative physical insight and they leave rigorous formulations to the mathematicians. The economic theorists' overvaluation of rigor is a symptom of their undervaluation of explanatory power. The truth is its own justification and needs no help from rigor." *The Bounds of Reason: Game Theory and the Unification of the Behavioral Sciences* (Princeton, NJ, and Oxford, UK: Princeton University Press, 2009), xvii-xviii.

description, not as a reified entity that causes anything. Such systems exhibit certain characteristics of which one must be aware to grasp the significance of other elements of the DynCoopNet Project's name.

1) First, although many factors are involved in complex systems, system stability depends on a small number of variables, sometimes only one, which are always near instability.[16] The term "stability" does not mean that nothing happened during this four-century period, for the system was highly dynamic.

2) Second, such nonlinear dynamic systems admit only limited predictability, and research on them should not be directed to the study of long strings of linear causation but to identifying the system's characteristics for the understanding of it and of the transition to a different system.[17]

3) Third, within the dynamics of the system, new forms emerged, which could compensate for weaknesses in the system caused by the proximity to instability of the stabilitymaintaining factors. However, these weaknesses remained, and the complex, dynamic, nonlinear system of the First Global Age eventually entered into a period of as yet poorly understood systemic chaos, phase transition, and bifurcation during the period 1750-1850. Out of this transition appeared a new system, characterized by new forms of world interaction, institutional organization, values, and

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16   Hermann Haken, *Advanced Synergetics: Instability Hierarchies of Self-organizing Systems and Devices* (Berlin and Heidelberg, DE: Springer-Verlag, 1983). Rosser (From *Catastrophe* to Chaos, 54-61), after a thorough review of theories of complex systems, argues persuasively that Haken provides the most satisfactory understanding of such systems and, therefore, a point of synthesis for them.

17   On the limits of predictability in complex, dynamic, nonlinear systems, I follow the views of Puu, *Attractors, Bifurcations and Chaos*, and Rosser, *From Catastrophe to Chaos*. Elsewhere, Puu has shown that about 1960, economists moved away from nonlinear and spatial models, leading to distorted forecasts, the negative effects of which have become evident since he completed his chapter; see Puu, "Introduction to Mathematical Economics," in *Mathematical Models in Economics: UNESCO Encyclopaedia of Life Support Systems*, ed. Wei-Bin Zhang (Oxford, UK: Eolss Publishers, 2007), 78-117. Professor Puu is an associate of the DynCoopNet Project.

perspectives on the world.[18]

Self-Organizing Commercial Networks

For the investigation of cooperation, DynCoopNet focuses on a type of social network: commercial networks of merchants and others involved in the movement of products, capital, and information throughout an increasingly globalized economy. We understand these networks as largely self-organizing ones because in an open system, their participants most often created and shaped them toward increasing complication, rather than depending on the leadership of some authoritarian entity or individual, independent of the networks themselves.[19] Because of this self-organization, commercial and related social networks constituted important sources of creativity and innovation, which can be understood as the emergence of new forms.[20] Although its

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18   The point that after a phase transition to a new human system, the cultural environment would be dominated by new values and perspectives about the world, impairing the ability of people to understand their ancestors in the earlier system, was emphasized for me by the lecture of my DynCoopNet colleague Michael Sonis of Israel's Bar-Ilan University, entitled 'The Evolution of Complexity', for Idaho State University's Mathematics Colloquium, 27 February 2007.

19   For an understanding of self-organization in economics, see Friedrich A. Hayek, *Law, Legislation and Liberty: A New Statement of the Liberal Principles of Justice and Political Economy* (3 vols. Chicago, IL: University of Chicago Press, 1973-1979); Paul R. Krugman, *The Self-Organizing Economy* (Mitsui Lectures in Economics; Cambridge, MA, and Oxford, UK: Blackwell Publishers, 1996). Smuggling networks provide particularly striking examples of self-organization; for example, see Ángel Alloza Aparicio, *Europea en el mercado español: Mercaderes, represalias y contrabando en el siglo XVII* (Salamanca, SP: Junta de Castilla y León, Consejería de Cultura y Turismo, 2006); Emily Erikson and Peter Bearman, "Malfeasance and the Foundations for Global Trade: The Structure of English Trade in the East Indies, 1601–1833," *American Journal of Sociology* 112, no. 1 (July 2006): 195–230; B. J. López Belinchón, "'Sacar la sustancia al Reino': Comercio, contrabando y conversos portugueses, 1621-1640," Hispania 61, no. 209 (2001): 1017-1050; Zacarías Moutoukias, *Contrabando y control colonial en el siglo XVII: Buenos Aires, el Atlántico y el espacio peruano* (Buenos Aires, Argentina: Centro Editor de América Latina, 1988); Hoh-Cheung Mui and Lorna Mui, "Smuggling and the British Tea Trade before 1784," *American Historical Review* 74 (1968): 44-73; Ernst Pijning, "A New Interpretation of Contraband Trade," *Hispanic American Historical Review* 81, no. 3-4 (2001): 733-738; George D. Winius, "The 'Shadow Empire' of Goa in the Bay of Bengal," *Itinerário* 7, no. 2 (1983): 83-101.

20   In addition to the literature cited in note 13, on social networks and the emergence of new

call to recognize the networks connecting humans to the natural world is useful, DynCoopNet largely rejects Bruno Latour's Actor-Network Theory (ANT) because of its insufficient attention to the variable importance or weight of networked connections and to the plasticity of identity, which permits an actor to participate in different networks.[21] Postulating the existence of polymorphous network domains permits DynCoopNet to capture the complications of networked activities revealed in the surviving documents about actors in the period 1400-1800.[22]

Within the system of the First Global Age, events periodically disrupted these commercial networks. Sometimes, disruptions

forms, see Mark S. Granovetter, "Economic Action and Social Structure: The Problem of Embeddedness," *American Journal of Sociology* 91 (1985): 481-501; Torsten Hägerstrand, *Innovation Diffusion as a Spatial Process*, trans. Allan Pred, with assistance of Greta Haag (Chicago, IL: University of Chicago Press, 1967); Janet T. Landa, *Trust, Ethnicity and Identity: Beyond the Institutional Economics of Ethnic Trading Networks, Contract Law and Gift Exchange* (Ann Arbor: University of Michigan Press, 1994); Janet T. Landa, "Doing the Economics of Trust and Informal Institutions," in *Foundations of Research in Economics: How Do Economists Do Economics?* eds. S. G. Medema and W. J. Samuels (Brookfield, VT: Edward Elgar, 1996), 143-159; Alan Latham, "Retheorizing the Scale of Globalization: Topologies, Actor-Networks, and Cosmopolitanism," in *Geographies of Power, Placing Scale*, eds. A. Herod and M. W. Wright (Oxford, UK: Blackwell, 2002), 115-144; editors' introduction, *Spinning the Commercial Web: International Trade, Merchants, and Commercial Cities*, c. 1640-1939, eds. M. Schulte Beerbühl and J. Vögele (Frankfurt am Main et al: Peter Lang, 2004); Michael Sonis, "A Territorial Socio-ecological Approach in Innovation Diffusion Theory: Socio-ecological and Economic Interventions of Active Environment into Territorial Diffusion of Competitive Innovation," *Sistemi Urbani* 1-2-3 (1991): 29-59; Michael Sonis, "Innovation Diffusion, Schumpeterian Competition and Dynamic Choice: A New Synthesis," *Journal of Scientific & Industrial Research (Special Issue on Mathematical Modeling of Innovation Diffusion and Technological Change)* 51, no. 3 (1992): 172-186; Michael Sonis, "Major Actors in Innovation Diffusion Process," *Complexity, Knowledge and Innovation Systems*, eds. M. Fischer and J. Froelich (Berlin and Heidelberg, DE, and New York, NY: Springer-Verlag, 2001), 317-341; Michael Sonis, "Innovation Diffusion Theory: 100 Years of Development," *Tool Kits in Regional Science: Theory, Models, and Estimation*, eds. Michael Sonis and Geoffrey J. D. Hewings (Berlin and Heidelberg, DE: Springer-Verlag, 2009), 243-271.

21   Bruno Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory* (Oxford, UK: Oxford University Press, 2005).

22   Our perspective on polymorphous network domains and the plasticity of personal identity, which permits individuals to contribute to multiple social networks, is informed by the work of Harrison C. White (born 1930); see especially his "Social Networks Can Resolve Actor Paradoxes in Economics and in Psychology," *Journal of Institutional and Theoretical Economics* 151 (1995): 58-74; *Markets from Networks: Socioeconomic Models of Production* (Princeton, NJ: Princeton University Press, 2002); *Identity and Control: How Social Formations Emerge* (Princeton, NJ: Princeton University Press, 2008 [1st ed. 1992]).

occurred because of processes within the human system itself, such as war, for example, but disruptions also occurred because of the interactions of the human system with complex, dynamic, nonlinear systems in the natural world, such as disease epidemics or earthquakes, to pick two disruptive interactions of concern in 2010. To some extent, we can think of these disruptions as "noise" within the system.[23] To maintain system stability, actors, both men and women, had to counter the disruptions by constituting more robust networks, but the resulting denser webs of connections permitted even more widespread future cascades of disturbances. In the later eighteenth century, such a cascade of innovation initiated a transition to a new historical period, the Second Global Age in which we now live. By combining a social network approach with a world systems analysis, we offer a world historical account that addresses larger issues of network dynamics and provides a solution to the common criticism of world system analysis that it ignores the relationships between the local and the larger system.[24]

I will dwell on this point about disruptions of commercial networks because it is fundamental for an understanding of the next section of this chapter. Nonlinear dynamics permit only limited predictability. Think about weather forecasting. In other words, changes appeared in the First Global Age rather suddenly,

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23   See Jordi García-Ojalvo and José M. Sancho, *Noise in Spatially Extended Systems* (New York, NY: Springer-Verlag for the Springer Institute for Nonlinear Science Series, 1999).

24   Reviewers have frequently leveled this complaint at major works of those using world-systems analyses: against, for example, Christopher Chase-Dunn and Thomas D. Hall, *Rise and Demise: Comparing World-Systems* (Boulder, CO: Westview Press, 1997); Andre Gunder Frank, *ReORIENT: Global Economy in the Asian Age* (Berkeley and Los Angeles: University of California Press, 1998); Immanuel Wallerstein, *The Modern World-System*, 3 vols. (New York, NY, and San Diego, CA: Academic Press, 1974-89). For a review that does a particularly good job of exposing these deficiencies, see Kalala Ngalamulume, "Is Total History Possible?" Review of Donald R. Wright, *The World and a Very Small Place in Africa: A History of Globalizaion in Niumi, The Gambia, H-Africa, H-Net Reviews* (March, 2009), URL: http://www.h-net.org/reviews/showrev.php?id=24284 (accessed May 15, 2010).

without a long period of development. For reasons best explained in narratives, innovations cascaded through social networks with every disruption, threatening the stability of the existing system and challenging actors, both men and women, to weave greater network robustness in an effort to protect themselves from disaster and enhance their ability to survive and prosper, however they understood these concepts. Therefore, knowledge about cooperation will not come from continuous narratives of developments over three or four centuries. Instead, each narrative would focus on the way that a cascade of disruptions and innovations prompted actions to create more robust commercial and other social networks within an expanding geographic space, a process that permitted the emergence of new forms in the social and cultural environments of human action. This emergence of new forms sustained the system by dealing with weaknesses, which would otherwise have led to system collapse. For example, the fifteenth-century expansion of the system could have produced its collapse, but this did not happen. In general terms, this process increased network density and made the system more robust or stable. However, the complicated ways that multiple networks interlinked with each other over expanding geographic spaces enhanced possibilities that cascading disruptions would affect ever larger portions of the world system and entail ever more elaborate efforts, ultimately frustrated, to repair damage and prevent such sizable disruptions in the future.[25]

　　"Ultimately frustrated" because as a consequence of the

25　　For recent work on such cascades, see Sergey V. Buldyrev, Roni Parshani, Gerald Paul, H. Eugene Stanley, and Shlomo Havlin, "Catastrophic Cascade of Failures in Interdependent Networks," *Nature* 464, no. 7291 (April 15, 2010): 1025-28; doi: 10.1038/nature08932; Alessandro Vespignani, "The Fragility of Interdependency," *Nature* 464, no. 7291 (April 15, 2010): 984-5; doi: 10.1038/464984a.

nature of complex systems, the sources of systemic instability would not be eliminated by such repairs, the increased network density and interlinking would make it ever more likely, in an event that could not have been predicted, that some disruption would cascade so widely that the system would enter a period of chaos and transition to a new system. Sometime in the eighteenth century, one or more of the stability-maintaining "control" variables became unstable, and this situation led to system instability and the development of a period of bifurcation around which a new system organized.

The sudden weakness of a variable propagated throughout the system from a cluster of individuals who could spread their influence through commercial and other social networks by their impact on individuals who were near them in the nodes of these networks and wished to enhance their ability to survive and prosper.[26] Researchers cannot understand the dramatic suddenness, in relative terms, of this process unless they grasp how individuals were involved in multiple social networks and how this involve-

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26   See Duncan J. Watts, *Six Degrees: The Science of a Connected Age* (New York and London: W. W. Norton, 2003), 229-44 and 250-2. Also suggestive are: Per Bak, *How Nature Works: The Science of Self-organized Criticality* (New York, NY: Copernicus Press for Springer Verlag, 1996); Philip Ball, *Critical Mass: How One Thing Leads to Another* (New York, NY: Farrar, Straus and Giroux, 2004). DynCoopNet assumes that the cooperation-based networks we study were largely self-organizing. In the natural world, self-organization produces regular patterns, which can be defined mathematically and visualized. Will we eventually be able to recognize such mathematically definable patterns in human systems? How do patterns developing from self-organization in natural systems couple with the human system? On such patterns in the natural world, see, Philip Ball, *The Self-made Tapestry: Pattern Formation in Nature* (Oxford, UK: Oxford University Press, 1999); Philip Ball, Nature's Patterns: A Tapestry in Three Parts, 3 vols. (Oxford, UK, and New York, NY: Oxford University Press, 2009). In his book The Tipping Point: *How Little Things Can Make a Big Difference* (Boston, MA: Little, Brown, 2000), Malcolm Gladwell suggests that it is adoption by the influential and highly connected that leads to a cascade, but Watts' current work shows that such elite influence probably does not exist. For example, see Duncan J. Watts and Peter S. Dodds, "Influentials, Networks, and Public Opinion Formation," *Journal of Consumer Research* 34, no. 4 (December 2007): 441-58.

ment required them to shape their social identities depending on the variable contexts of their interactions with others. The global cascade of system instability depended on the irregular linkage of different social networks so that the sources of instability could be propagated before any system-saving repair was possible.

Dynamics GIS and Knowledge from Complicated Narratives

Because Monica Wachowicz and I have written a chapter on geographic information systems (GIS) for this book (see chapter 2), I will limit this section to an explanation of the role of GIS in DynCoopNet Project. As the section title, I employ the "Dynamics GIS" phrase invented by our DynCoopNet colleague May Yuan, for it expresses well the challenge for DynCoopNet researchers.[27] DynCoopNet demands that to understand cooperation in commercial and other social networks of the First Global Age, 1400-1800, we narrate the stories of the development of these networks. In order to produce narratives that are sufficiently complicated to reveal the bases for the high level of cooperation we have observed, we must insert these networks in the dynamic geographic context,

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27   See May Yuan, "Dynamics GIS: Recognizing the Dynamic Nature of Reality," *ArcNews* 30, no. 1 (spring 2008): 1, 4-5, and http://www.esri.com/news/arcnews/spring08articles/dynamics-gis.html (accessed May 15, 2010). In her workshop in June 2006, at the summer assembly of the University Consortium for Geographic Information Science (UCGIS), May Yuan helped me develop the section on spatial-temporal GIS, which appeared in the DynCoopNet full proposal in September 2006. Based on a position paper that I had submitted, she and Kathleen Steward Hornsby had already invited me to participate in their workshop outside of Baltimore, Maryland (USA), in October 2006. On the rich results of the latter workshop, see Kathleen Stewart Hornsby and May Yuan, eds., *Understanding Dynamics of Geographic Domains* (Boca Raton, FL, and New York, NY: CRC, 2008); May Yuan and Kathleen Stewart Hornsby, *Computation and Visualization for Understanding Dynamics in Geographic Domains: A Research Agenda* (Boca Raton, FL: CRC, 2008).

which we wish to express in a GIS capable of updating of multiple data types. This geographic context accounted for many of the network disturbances, both in terms of the nonlinear dynamics of natural systems and of the opportunities provided by the increased space of human activity and connections among locations of human habitation. These disturbances of existing social networks produced human activity to elaborate more robust networks, leading to the emergence of new forms of importance for understanding cooperation. In a broader perspective, the integration of dynamic social network analysis within the context of a dynamic GIS addresses the needs of researchers interested in coupled natural and human systems, to use a concept of interest to the U.S. National Science Foundation (NSF).[28]

An evolutionary GIS with the capacity to update information at appropriate time intervals would provide the basis for the necessary complicated narratives. Oversimplifying a bit, GIS permits us to treat each data type as a separate layer, which can, on the computer screen, overlay other data layers to see relationships among them. When their information is organized in this form, historians find it much easier to recombine and disaggregate data, to display selected features, and to explore what is known in ways that expose unexpected relationships and facilitate analysis of the interrelationship of multiple factors characteristic of difficult problems. As the authors of the Organization of American Historians' LaPietra Report correctly emphasize, the history of no place can be adequately understood without taking into account how that place has been connected to other places, and GIS facilitates linking and

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28   For more on this concept, see the web site of CHANS-Net, the International Network of Research on Coupled Human and Natural Systems, http://www.chans-net.org/default.aspx (accessed May 15, 2010).

comparing places within different spatial scales. Particularly when a place is a country or large region, it is difficult for a single historian to master what is known about multiple locations, and GIS provides an excellent platform for multidisciplinary collaboration among researchers. Finally, GIS permits visualization of relationships. Visualization reduces the cognitive weight on even the experienced analyst when the quantity of information is great, a problem is complex, and alternative solutions are numerous and surpass the capabilities of human reason.[29]

To take advantage of the use of GIS for keeping track of the connections of social network nodes to place and for spatial analysis and visualization, historians confront GIS technologies are difficult for historical researchers and their students to master, and to deal with the problem, DynCoopNet established a multidisciplinary, collaborative research paradigm, which remains unusual within the discipline of History. Within this collaborative program, DynCoopNet seeks to transform current GIS, which are largely static, deal poorly with temporal factors of change and movement, and do not permit dealing simultaneously with the interactions of more than a few variables. The assumption that optimization is the only rational goal distorts understanding of human action in its social and cultural environments. Yet bringing all of the necessary factors together requires mathematics beyond the grasp of almost all social scientists, underlining the need for a broad, transformative, multidisciplinary approach.[30] Historical study and

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[29] These visualizations of reality are abstractions, and like the articles and books written by historians, which are also abstractions of reality, cartographic and other visualizations should be judged on the degree to which they increase our understanding of the real world. This point is central to David J. Staley, *Computers, Visualization, and History: How New Technology Will Transform Our Understanding of the Past* (Armonk, New York: M. E. Sharpe, 2003).

[30] For an idea of the level of mathematics required, see Tönu Puu, "Optimality versus Stability:

the development of narrative knowledge through the use of GIS require this transformation. Finally, computers require numerical precision, but much significant historical data are qualitative, imprecise, ambiguous, incomplete, uncertain, contradictory, and otherwise messy and, therefore, difficult to represent in current GIS.[31] As research extends to centuries before 1800, the data problems become worse. The mathematical modeling required for spatial-temporal GIS, dynamic social network analysis, analyzing spatial nonlinear dynamics, and dealing with messy data demand multidisciplinary collaboration.[32]

Pattern Formation in Spatial Economics," in *Tool Kits in Regional Science: Theory, Models, and Estimation*, eds. Michael Sonis and Geoffrey J. D. Hewings (Berlin and Heidelberg, DE: Springer-Verlag 2009), 155-161; Michael Sonis, "Theories and Models Inspired by Empirical Regularities of Socio-Economic Spatial Analysis," in *Tool Kits in Regional Science: Theory, Models, and Estimation,* Michael Sonis and Geoffrey J. D. Hewings (Berlin and Heidelberg, DE: Springer-Verlag, 2009), 293-302.

31   Ian N. Gregory and Paul S. Ell, *Historical GIS: Technologies, Methodologies and Scholarship* (Cambridge, UK: Cambridge University Press, 2008); Ian N. Gregory and Richard G. Healey, "Historical GIS: Structuring, Mapping and Analysing Geographies of the Past," Progress in Human Geography 31, no. 5 (2007): 638-653, DOI: 10.1177/0309132507081495; J. B. Owens, "What Historians Want from GIS"; J. B. Owens, "Historical Studies, GIS for," in *Encyclopedia of Geographic Information Science*, ed. Karen Kemp (Thousand Oaks, CA: Sage, 2008), 220-21.

32   The full value of the DynCoopNet paradigm could not be realized because the collapse of TECT networking funding in December 2008 made it impossible for DynCoopNet to organize our planned third TECT strategic workshop. This workshop would have brought together animal ecologists, anthropologists, economists, historians and others interested in cooperation research with geographic information scientists and mathematical modelers of spatial nonlinear dynamics and social network analysis. To pick up the pieces, DynCoopNet researchers are submitting funding proposals. So far, the U.S. National Science Foundation (NSF) has funded the SOCNET Project ("Understanding Social Networks within Complex, Nonlinear Systems: Geographically-Integrated History and Dynamics GIS") through its Cyber-Enabled Discovery and Innovation (CDI) program for over US$1.7 million for four years, beginning on October 1, 2009 (Idaho State University $1,290.704, lead PI J. B. Owens, OCI-0941371; University of Oklahoma, $471,193, PI May Yuan, OCI-0941501). Besides Owens and Yuan, the other DynCoopNet members involved in SOCNET are Emery A. Coppola, Jr., President and Principal Scientists, NOAH, L.L.C.; Aldo Gangemi, Semantic Technology Laboratory, Italian National Research Council, Rome; Monica Wachowicz, Center for Geoinformation, Wageningen University and Research Centre, The Netherlands.

The world is fuzzy

Data quality forms a barrier to precision. However, the complexity of the human system of the First Global Age and its relation to geography constitutes a veritable fortress against numerical precision.[33] Historians frequently resist any demands that they force their information into fixed categories required by a computational environment because so often, they feel that vital characteristics of some information will be lost when they do not fit precisely into a particular box. Even a document as seemingly precise as a contract remains surrounded by imprecise factors, which will influence whether or not the agreement works out as planned as much as the contract terms themselves.[34] As the "domain" experts, after years of reading the surviving documents and examining other period objects, historians develop a sense of the system, of degrees in the characterization of human behavior, and of the meanings conveyed in the natural language of the people they study. The historians find shades of meaning in the evidence, which defy conventional numerically based approaches. Animal ecologists and geographers often confront the same ambiguity. For example, where is southeastern Spain? "Essentially, vagueness results in a range of interpretations for a place reference and a range of borderline values for the spatial footprint of each reference."[35]

33   Peter A. Burrough and Andrew U. Frank, eds., *Geographic Objects with Indeterminate Boundaries* (London, UK: Taylor & Francis, 1996); George A. Miller, "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information," *Psychological Review* 63 (1956): 81-97; Charles C. Ragin and Paul Pennings, "Fuzzy Sets and Social Research," *Sociological Methods & Research* 33, no. 4 (May 2005): 423-30.

34   Stewart Macauley, "Noncontractual Relations in Business: A Preliminary Study," *American Sociological Review* 28 (February 1963): 55-67; Ian R. Macneil, *The New Social Contract: An Inquiry into Modern Contractual Relations* (New Haven, Conn.: Yale University Press, 1980).

35   Linda L. Hill, *Georeferencing: The Geographic Associations of Information* (Cambridge, MA: MIT Press, 2006), 28-29 (section "Vagueness of Georeferencing").

Game theory produces interesting but oversimplified results, and the application to cooperation in the real world falls short of the precision game theory proponents often claim for their controlled experiments with human subjects playing games.[36] But we have a way forward.[37]

In 1964, some friend stood up Lotfi Zadeh (born 1921), a Berkeley electrical engineering professor, for dinner. So as not to waste the evening, he commenced work on a solution to the incompatibility of complexity and precision. The following year, he published his now-classic paper on what came to be known as fuzzy logic or fuzzy set theory.[38] In the article, he proposed a means to think precisely about ambiguous things without losing a record of the ambiguity. Fuzzy logic possesses several strengths important for DynCoopNet. It provides an effective means to move efficiently from available data to developing mathematical models as a basis for analysis and knowledge. Data can be imprecise or vague. Researchers can employ natural language linguistic variables that are subjective in nature (for example, "trust"). Fuzzy

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[36]   For intriguing, suggestive examples of ways that game theory could be used within the particular context of the complex, dynamic, nonlinear system of the First Global Age, see Ken Binmore, *Natural Justice* (New York: Oxford University Press, 2005); Herbert Gintis, *The Bounds of Reason: Game Theory and the Unification of the Behavioral Sciences* (Princeton, NJ, and Oxford, UK: Princeton University Press, 2009). To quote Gintis (p. xv), "This approach [that which the 'book champions'] holds that human behavior is most fruitfully modeled as the interaction of rational agents with a social epistemology, in the context of social norms that act as correlating devices that *choreograph* social interaction."

[37]   For the initial DynCoopNet formulation of the use of fuzzy logic, see Emery A. Coppola, Jr. *et al.*, "Fuzzy Rule-Based Modeling of Degrees of Trust in Cooperation-Based Networks: Close Research Collaboration among Domain Experts (Historians) and Mathematical Modelers" (paper presented by Owens to the TECT strategic workshop, Technical University of Madrid, Spain, September 25-26, 2008), http://mapas.topografia.upm.es/Dyncoopnet/presentations/Madrid_fuzzy_owens.pdf (accessed May 15, 2010).

[38]   Lotfi A. Zadeh, "Fuzzy Sets," *Information and Control* 8 (1965): 338-353. Zadeh explains well key elements of fuzzy logic in his articles: "Why the Success of Fuzzy Logic Is Not Paradoxical," *IEEE Expert* 9, no. 4 (1994): 43-45; "Toward a Theory of Fuzzy Information Granulation and its Centrality in Human Reasoning and Fuzzy Logic," Fuzzy Sets and Systems 90 (1997): 111-127.

logic uses assessment rules, which are created by the researcher and are transparent and thus readily understood and evaluated by other researchers. Finally, the rules can bound the expected range of system behavior under different conditions, which facilitates effective modeling.

Fuzzy logic uses linguistic variables as labels for fuzzy sets to provide an approximate characterization of complex or ill-defined phenomena.[39] These labels admit the use of "hedges" (predicate modifiers). Thus, humans speak in terms of "more or less", "slightly", "somewhat", "much" (as in, "is much heavier"), "is close to", "very" (as in, "is very young"), "quite" (as in, "is quite attractive"), "extremely", and completely".[40] These linguistic variables represent expressions in natural language of social norms, which are understood by those in communication because they share to some degree a common "sociological citizenship" (to use the term of Jeffrey Alexander).[41] We do not share this sociological citizenship of people who lived in the First Global Age, and therefore, we must represent and model this unfamiliar human system in ways that respect its uncertainty and imprecision.

Once the fuzzy sets are defined in this manner, the researcher creates membership functions to characterize the degree of membership in a fuzzy set. In other words, the transition between membership in a particular set and non-membership remains gradual, just as it is perceived by the domain expert.

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39   Lotfi A. Zadeh, "The Concept of a Linguistic Variable and its Applications to Approximate Reasoning," *Information Sciences* 8 (1975): 199-249 (Part I); *Information Sciences* 8 (1975): 301-357 (Part II); *Information Sciences* 9 (1975): 43-80 (Part III).
40   Lotfi A. Zadeh, "A Fuzzy-set-theoretical Interpretation of Linguistic Hedges," *Journal of Cybernetics* 2 (1972): 4–34.
41   Jeffrey C. Alexander, *Action and Its Environments: Toward a New Synthesis* (New York, NY: Columbia University Press, 1988).

The researcher preserves the qualities of data that do not fit comfortably in any established set, avoiding the sense that an improper, arbitrary judgment motivates an assignment. So that others may evaluate the choices made by the researcher, he or she characterizes the relationships between the linguistic variables by a series of fuzzy conditional ("If, Then") statements or "rules", which can be displayed as part of the metadata for the data set and in resulting papers. The process of modeling on the basis of fuzzy logic demands the continuous, iterative involvement of the domain expert on the historic system throughout the process in order to improve, on the basis of outcomes, the axioms or rules. To grasp the meaning of a given situation within a complex system, the researcher employs a reasoning method or algorithm to combine the fuzzy rules proportionately to the degree to which they apply, and he or she explains this method.[42] Thus, other scholars can debate the appropriateness of both the rules and the method, contributing to a progressively greater understanding of the system and vital aspects of human action such as cooperation. From the application of the method to the rules, the researcher obtains a "crisp" value, which can be utilized within a computational environment such as a GIS or an analysis of a social network.[43]

Such a method works better than recourse to statistics

42   Lotfi A. Zadeh, "Outline of a New Approach to the Analysis of Complex Systems and Decision Processes," *IEEE Transactions on Systems, Man and Cybernetics, SMC-3* (1973): 28-44; Lotfi A. Zadeh, "A Fuzzy-algorithmic Approach to the Definition of Complex or Imprecise Concepts," *International Journal of Man-Machine Studies* 8 (1976): 249-291.

43   Fuzzy logic approximates well the goals of those who propose various forms of "soft computing" to deal with qualitative data. See, Lotfi A. Zadeh, "Fuzzy Logic, Neural Networks and Soft Computing," *Communications of the ACM* 37, no. 3 (1994): 77-84; Lotfi A. Zadeh, "Fuzzy Logic = Computing with Words," *IEEE Transactions on Fuzzy Systems* 2 (1996): 103-111. For a positive evaluation of the use of fuzzy logic in another domain, see Eviatar Tron and Michael Margaliot, "Modeling Observed Natural Behavior Using Fuzzy Logic," FUZZ '03. *The 12th IEEE International Conference on Fuzzy Systems,* 2003 1 (25-28 May 25-28, 2003): 74 – 78, DOI: 10.1109/FUZZ.2003.1209340.

or probability when dealing with the First Global Age because, especially given the limitations of our sources of information, we never know the statistical universe with which we are dealing.[44]

DynCoopNet Norms of Data-Sharing, Collaboration and Joint Publication

From the beginning of DynCoopNet, we recognized that some of those being asked to collaborate came from disciplines such as History, which lack any tradition or official norms for the use of shared, distributive data, for collaboration, and for joint publication. Therefore, to build the necessary research infrastructure, we established project norms and the goal of getting these norms, or something similar, enacted as professional standards by major historical and other scholarly organizations that lack such standards.[45] Because DynCoopNet intended to deal with cooperation in commercial networks over large geographical spaces, ultimately global, we based the project standards on those of organizations whose reach focus is also spatial extensive. The disciplines of Atmospheric Science and Oceanography deal with open systems covering large geographic spaces, and publication in these fields depends on ac-

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44   Lotfi A. Zadeh, "Probability Theory and Fuzzy Logic Are Complementary Rather Than Competitive," *Technometrics* 37 (1995): 271-276; Lotfi A. Zadeh, "Probability Theory and Fuzzy Logic" (lecture given to the Society for Industrial and Applied Mathematics, Philadelphia, PA, USA, December 9, 2002), http://www.ieeesmc.org/announcements/Newsletter/JAN2003/Probability%20Theory%20and%20 Fuzzy% 20Logic.pdf (accessed May 15, 2010). Of course, when the data permit, fuzzy logic and statistical probability can be employed together with profit; see, Michael Smithson, "Fuzzy Set Inclusion: Linking Fuzzy Set Methods with Mainstream Techniques," *Sociological Methods & Research* 33, no. 4 (May 2005): 431-461; and some of the examples in Michael Smithson and Jay Verkuilen, *Fuzzy Set Theory: Applications in the Social Sciences* (Thousand Oaks, CA: Sage, 2006).
45   The DynCoopNet standards, which we adopted at our meeting in Budapest in July 2007, can be downloaded at the URL http://idahostate.academia.edu/documents/0010/2787/Professional_Standards_DynCoopNet.pdf (accessed May 15, 2010).

cess by scientists to data sets prepared as a result of research done by others. Therefore, DynCoopNet took these fields as models for the data and authorship policies. In particular, we adapted sections available at that time from the "Ethical Guidelines to Publication of Chemical Research of the American Chemical Society (ACS),"[46] the "Guidelines to Publication of Geophysical Research of the American Geophysical Union (AGU),"[47] and the "Policy on Referencing Data in and Archiving Data for AGU Publications."[48] The DynCoopNet data policy was adopted in order to encourage historical researchers to make available the underlying data on which their papers, articles, and books are based for long-term access, to archive their data in approved data centers, and to recognize in their publications the valuable role of the researchers who collect and prepare important data for use by the global historical research community. The joint publication standards were designed to eliminate or reduce conflicts over who should be included as an author of a paper, article, or book and the order in which the authors' names should be listed.

Thus far, historical organizations have not adopted standards of this type to foment collaborative research. For example, when Owens proposed to the professional division of the American Historical Association (AHA), the organization that claims to represent the interests of all historians in the United States, he was told that (1) historians did not collaborate and (2) the AHA already had standards for collaboration. Of course, neither statement is true. The vice president of the division recognized no

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46   A subsequently revised version can be found at the URL http://pubs.acs.org/page/policy/ethics/index.html (accessed May 15, 2010).

47   http://www.agu.org/pubs/authors/manuscript_tools/journals/pub_guidelines.shtml (accessed May 15, 2010).

48   http://www.agu.org/pubs/authors/policies/data_policy.shtml (accessed May 15, 2010).

contradiction between the two claims.

Overview

No single discipline offers the necessary concepts, methodologies, and tools to understand complex historical systems, the dynamic social networks within them, and the transformations of such systems. With geographically-integrated history, DynCoopNet created a transformative disciplinary framework to focus multidisciplinary research on the difficult problem of cooperation among humans. By framing the First Global Age, 1400-1800, as an open, complex, dynamic, nonlinear system, DynCoopNet challenges the myth histories around which history and the historical sciences were created as academic disciplines beginning in the mid nineteenth century: the rise of the State, often as the Nation-State (in Europe), the rise of Capitalism (in Europe), and the rise of the Modern Individual or Individualism (in Europe). All three developments were taken as the products of a special European rationality and the necessary hallmarks of "modernity," which the peoples of Greater Europe had the responsibility to diffuse throughout the rest of the world. These organizational myths of historical research emerged as new forms within the intense struggles to shape the Second Global Age, which was developing from the phase transition that ended the First Global Age during the period 1750- 1850. To justify themselves, mid nineteenth-century intellectuals and movements projected these developments back into the First Global Age, usually to about 1500. Because people living in the new system responded to different

values and perspectives about the world from those of who lived in the earlier system, they had trouble understanding their predecessors. Their myth histories guided the formation of archives and the search for information, and as a consequence researchers missed the importance of the puzzlingly high levels of cooperation among merchants and officials and frequently ignored the roles of women within the social networks, which sustained connections over often huge geographic distances. By formulating the First Global Age as a specific world system, DynCoopNet highlights the deficiencies of Eurocentric forms of historical periodization and of teleological notions, such as the existence of an "early modern" era much longer than the subsequent age it supposedly prepared.[49]

By stating that the complex system of the First Global Age was characterized by nonlinear dynamics, DynCoopNet challenges Eurocentric myth histories in another way. Complex, dynamic, nonlinear systems admit quite limited predictability. New developments emerged relatively suddenly and cannot be accounted for by telling centuries-long narratives. Instead, reliable narrative knowledge flows from stories about the emergence of new forms within the social and cultural environments and their impact on human action. Moreover, such narrative knowledge should reveal how the emerging forms aligned with components of the human and natural systems and which variables maintained system stability until they entered into a period of instability,

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[49]   Many writers have exposed the Eurocentric nature of much writing and teaching in history and historical social sciences. DynCoopNet was directly inspired by one of them, Andre Gunder Frank (J. B. Owens, "What Kind of System Is It?"). For a particularly devastating account of Eurocentric historiography, see James M. Blaut, *The Colonizer's Model of the World: Geographic Diffusionism and Eurocentric History* (New York, NY: Guilford Press, 1993). On the teleological concept "early modern," see Jack Goldstone, "The Problem of the 'Early Modern' World," *Journal of the Economic and Social History of the Orient* 41 (1998), 249-282; Rudolph Starn, "The Early Modern Muddle," *Journal of Early Modern History* 6 (2002), 296-307.

causing the system to move into chaos, bifurcation, and a phase transition.

To understand cooperation, these narratives focus on social networks. Historians have trouble telling these stories because human self-identity is fluid enough for people to participate simultaneously in multiple networks. These self-organizing networks likely produced patterns, which must be detected and expressed mathematically if they are to be understood. Periodically, disruptions threatened one or more of their networks, and people fashioned new networks, which they uselessly hoped would be sufficiently denser and more robust to prevent future threats. As network connectedness became greater and extended over larger geographic spaces, new forms, which emerged through this process of network disruption and fabrication, could cascade more rapidly and more widely. DynCoopNet hypothesizes that one or more of these new forms, challenging in some way one or more stability-maintaining "control" variables within the world system, cascaded so quickly throughout a large area that the system became unstable. This vision provides a new scope for telling dramatic narratives of the kind that have made historical writing so popular.

Yet these new narratives must be more complicated because they tell stories that connect local developments to the global. Moreover, they recount aspects of a human system continuously coupled to the nonlinear dynamics of natural systems and a complex geography. To permit the formulation of sufficiently complicated narratives for understanding cooperation, DynCoopNet proposed the creation of true spatial-temporal geographic information systems (GIS) to organize, analyze, and visualize the data about such

processes. In part, a dynamic GIS required the use of mathematical expressions of the various processes and the mathematical integration of these expressions into a common system. The level of difficulty of the mathematics involved proved to be well beyond the experience of most social scientists.

To increase the research difficulty of the project, data drawn from the surviving sources about the First Global Age is almost always ambiguous, uncertain, and just plain messy. Moreover, the information about human systems lacks the precision to which mathematical modelers of physical systems are accustomed. To pull this messy and imprecise information into a computation environment necessary for the use of GIS software and that for social network analysis, for cooperation research, DynCoopNet proposed the application of fuzzy logic (or fuzzy set theory), and we set about designing a form of fuzzy rule-based modeling that would meet the demands of historians and historical social scientists.

In conclusion, the different components of DynCoopNet's research environment and vision opened multiple spaces for interdisciplinary collaboration in an effort to generate new scientific ideas. As publications continue to emerge in the coming years that account for the emergence and maintenance of high levels of cooperation in the self-organizing commercial networks of the First Global Age, we will see if these radically new ideas transform existing disciplines and lead to the emergence of new disciplines, which break down many of the academic barriers that now constrain research, teaching, and cognitive development. We owe a great debt to the founders of TECT and to the European Science Foundation for providing us with this splendid opportunity for furthering such an ambitious research agenda.

Dynamics of Trade Networks: The Main Research Issues on Space-Time Representations[50]

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Introduction

Space-time representations deal with how we humans understand ourselves and our interactions with the geographical space. They also deal with developing computational models that are linked with the exploratory analysis of any geographical phenomena, such as trade networks. The development of the early space-time representations can be traced back to the early Fifteenth Century, when the Prince Henry the Navigator (1394-1460), a Portuguese royal prince, soldier, and patron of explorers, is often credited with originating the Age of Discovery.[51] For the first time, the information about sea voyages and land explorations were compiled using a systematic approach that has led to the production

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51   P. Longley, M. F. Goodchild, D. J. Maguire, D. W. Rhind (eds.), *Geographical Information Systems: Principles, Techniques, Management and Applications*, vol. 1, 2nd edition, Geoinformation International, 2011.

of historical maps as the main representation for sharing and communicating the knowledge about the new discoveries.

Moreover, the information about trade networks is commonly found in text documents of any kinds (e.g. commercial letters and notarial registers). In fact, these text sources provide potentially important information that can be used to collectively represent the dynamics of the trade networks. Dynamics is by definition the synergy between space and time. The 16th century is consensually seen as the time of the "world economies"[52] or of the "world systems"[53] , or even as the "First Global Age", since a growing interconnectivity has taken place between several world spaces, being a geographical, social, or even in a cultural and cognitive spaces. However, the available text sources are usually qualitative, imprecise, ambiguous, incomplete, uncertain, contradictory, and otherwise messy and, therefore, difficult to be represented in any current GIS. [54]

One way of addressing this problem is developing space-time representations based on an exploratory process approach that supports attribute finding, conceptual interpretation, functional inference, context shifting, hypothesis testing and searching for limitations.[55] In this paper, we have focussed on the main research issues on developing space-time representations based on an

52   Fernand Braudel, *Civilization, and Capitalism, 15th–18th Centuries*, 3 vols. (New York: Harper and Row, 1981-1984).
53   Immanuel Wallerstein, *The Modern World-System*, 3 vols. (New York, NY, and San Diego, CA: Academic Press, 1974-89).
54   Ian N. Gregory and P. S. Ell, *Historical GIS: Technologies, Methodologies and Scholarship* (Cambridge, UK: Cambridge University Press, 2008); Owens, Geographically-Integrated, Connected World History: Employing Geographic Information Systems (GIS)," *History Compass* 5, no. 6 (October 2007): 2014-40; doi: 10.1111/j.1478-0542.2007.00476.x.
55   Donna J. Peuquet, *Representations of Space and Time.* (New York: The Guildford Press, 2002).

exploratory process that supports *context shifting*, which is the process of inspecting a text and considering an entity in varying contexts. The definitions of context that can be found in the literature range from 'a location – time, place, and possible world – at which a sentence is said'[56] to 'a psychological construct, a subset of the hearer's assumptions about the world',[57] to '[the] subset of the complete state of an individual that is used for reasoning about a given goal'.[58] Historians are quite good at determining a context for the interpretation of texts. For them, "meaning" does not adhere to the words themselves but relates directly to what is asserted by the use of the words and what other uses, available in the user's environment, are implicitly rejected. Therefore, a "context" is a dimension at which one or more historic actors (and one or more domain expert analysts) act, including by speaking or writing, to assert a "meaning" that involves an interpretation of some entity of the world.

We need context shifting for considering some logically coherent situation or potential reality, where various entities are treated as true, they are assumed to exist, and relations between them are supposed to hold withinspace-time representations indicating specific places, times, situations, the scope of certain existential assumptions expressing generalisations and beliefs. When a context is 'explained' or 'understood' it also means that some specific events or situations are represented as an instantiation of

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56   D. Lewis, "Index, Context, and Content", S. Kranger and S. Ohman, eds., *Philosophy and Grammar,* (D. Reidel Publishing Company, 1980).
57   D. Sperber and D. Wilson, Relevance: *Comunication and Cognition*, (Oxford-Malden, Blakcwell, 1986), p. 122.
58   F. Giunchiglia, "Contextual Reasoning", *Epistemologia*. Special Issue on *I Linguaggi e le Macchine*, vol. XVI (1993), pp. 345-364

some more tangible principle or concrete entity using different levels of complexity. In fact, contexts play an important role in understanding the general mechanisms that historians use to reason in such a way that a space-time representation can limit or enable the kinds of information represented, and the kinds of questions it can answer about trade networks.

State of Art on Space-Time Representations

Over the past years, the representations of space and time have been extensively discussed by different research communities. In Artificial Intelligence, mathematical foundations have been provided to support the representation of changes in space.[59] Temporal database approaches have been proposed to support database models and query languages for the representation of mobile objects.[60] Several studies have been carried out by the GIS community oriented to the temporal extension of current spatial database models.[61]

A range of modelling abstractions have been developed including the generic cause and effect relationship between an entity that has initiated a change and the entity that underwent

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59   L. Vieu, "Spatial representation and reasoning in artificial intelligence". In O. Stock (ed.) *Spatial and Temporal Reasoning*, (Kluwer Academic Publisher, 1997), pp.5-41

60   L. Forlizzi, R. H. Gütting, E. Nardelli and M. A. Schneider, A Data model and Data Structures for moving objects databases, *Proceedings of the ACM SIGMOD International Conference on Management of Data*, (Dallas, Texas, 2000).

61   J. P. Cheylan and S. Lardon, Toward a conceptual model for the analysis of spatio-temporal processes, in: Frank, A. U. and Campari, I. eds., Spatial Information Theory, (Berlin, Springer-Verlag, 1993), 158-176; A. U. Frank, Qualitative temporal reasoning in GIS - ordered time scales. *Proceedings of the Sixth International Symposium on Spatial Data Handling Conference*, (Edinburgh, Scotland, 1994); Peuquet, Op. Cit, Wachowicz, Object-Oriented Design for Temporal GIS. (Taylor and Francis, 1999); M. F. Worboys, A unified model of spatial and temporal information. *Computer Journal*, 1994, 37(1), pp.26-34.

such a change;[62] as well as modelling geometric information at the most precise scale, and automatically computing all geometries at less precise scales using generalisation.[63] Representing predefined patterns has also been proposed to describe a process that can generate a change: (i) a pre-formatted complex attribute that can describe the processes accountable for changing the value of an attribute, especially the value of a spatial attribute; (ii) a causal relationship that can describe the processes involving several entities; and (iii) a process entity type that can describe complex processes that are composed of other related sub-processes.[64]

Levels of detail in space-time representations have been previously addressed by research in multi-scale databases using hierarchical database structures[65] and database views.[66] However, a space-time representation for processing and reasoning using spatial data sets that are heterogeneous with regard to semantic

62   T. Griffiths, N. W. Fernandes, K. Paton, B. Mason, M. Huang, C. Worboys, C. Johnson and J. Stell, Tripod: A Comprehensive System for the Management of Spatial and Aspatial Historical Objects. *Proceedings 9th ACM Int. Symposium on Advances in Geographic Information Systems.* (Atlanta, GA, 2001); Pfoser D. and Tryfona, N. *Requirements, definitions and notations for spatio-temporal applications environments.* Chorochronos Tech. Report CH-98-09, November 1998.

63   J. C. Müller,J. P. Lagrange, R. Weibel, and F. Salgé, Generalization: state of the art and issues. In: J.C. Muller, J.P. Salge, and R. Weibel (eds), *GIS and generalization: methodology and practice*, (Taylor and Francis, 3-7. 1995); R. Weibel and Gg. Dutton, Generalizing spatial data and dealing with multiple representations, In P. Longley, M.F. Goodchild, D.J. Maguire, D.W. Rhind (eds.), *Geographical Information Systems: Principles, Techniques, Management and Applications*, vol. 1, 2nd edition, Geoinformation International, 1999.

64   J. Chomicki and J. Marcinkowski. Minimal-change integrity maintenance using tuple deletions. *Information and Computation,* 197 (1-2), (2005), pp. 90-121; C. Claramunt, C. Parent and M. Theriault, Design patterns for spatio-temporal processes. In: S. Spaccapietra and F. Maryanski (eds.), *Searching for Semantics: Data Mining, Reverse Engineering*, (New York: Chapman & Hall, 1997), pp. 415-428

65   S. Timpf, Hierarchical structures in map series. Ph.D. thesis, Technical University of Vienna, 1998; S. Zhou and C. B. Jones, *HCPO: an efficient insertion order for incremental Delaunay triangulation. Information Processing Letters*, (2005), 93(1), pp. 37-42.

66   Y. Bédard and E. Bernier, Supporting Multiple Representations with Spatial View Management and the Concept of "VUEL". *Proceedings of the Joint Workshop on Multi-Scale Representations of Spatial Data, ISPRS WG IV/3, ICA Communications on Map* Generalization, (Otawa, 2002).

and spatial resolution is still a research subject of interest and it addresses a timely topic. Some of the potential research issues at this foundational level include the connection between spatial and temporal attributes that still needs to be clarified: it is already clear that time cannot be treated as an extra spatial dimension and, so far, its linear and unidirectional nature – as opposed to the bi-directional nature of the space dimension – has not been properly investigated.[67]

In History, Fernand Braudel has urged for the integration of space in historical analysis pointing towards to what we call nowadays a "Geographically-Integrated History". For this historian, the use of a space-time representation plays an important role in the analysis necessary to comprehend men´s evolution, in the belief that change happens in a spatio-temporal framework. Recently, databases have been built by historians in order to gather digital data sources and therefore allowing this information to be analysed with new computational tools. Most of these databases have been developed for geometrical conflation and georeferencing of historical maps; reconstruction of past boundaries; and georeferencing of historical microdata (such as census or parish records). Another example includes the gazetteer of all of the locations included in the description of 139 routes published byVilluga in 1546 (and, therefore, relevant to movement in the world of Simón Ruiz). A high percentage of these unknown locations are waystations (ventas and others), and because many of these sites, particularly in the southern half of the peninsula,

67   D. Montello, Scale and multiple psychologies of space. In A. U. Frank and I. Campari (Eds), *International Conference GIS – From Space to territory: The theories and methods of spatio-temporal reasoning.* Lecture Notes Computer Sciences 639, (Springer Verlag, 1993), pp.136-152; and Pequet, *Op. Cit*, 2002.

were likely used for many centuries, back into Roman times, fairly accurate approximate locations should be useful for historical archaeologists (think about the possibility of locating a good site of a caravanserai from the Muslim period, for example). Although Villuga's book talks about "Spanish" routes, "Spain", in the absence of a country of that name, meant the entire Iberian Peninsula.

Choosing the conceptual view for a space-time representation

Although space and time are concepts inherently related, we encounter difficulties in thinking and hypothesising about them in equal terms. Langran[68] has coined the term "dimensional dominance" to illustrate how our reasoning is influenced by space-dominant or time-dominant conceptual views.

The *space-dominant conceptual view* focuses on the space-time representations of entities based on their thematic and geometric properties (Table 1). We start with reality and decide on the layers we would need to store enough observations (i.e. data) of that reality to answer the research question or questions we have posed. In other words, we define the criteria that must be included for our representation of an entity to be useful for our purposes, whether to portray, simulate, or predict its properties or behaviour.[69] Each layer corresponds exactly to the same absolute view of a geographical space so that, for example, a point in the x,y coordinate system of one layer will correspond precisely to the

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68   G. Langran, *Time in Geographic Information System*. (London, Taylor & Francis, 1992).
69   Adapted from Jack Horton and Kenneth Smith, "Concepts of Geographic Analysis" (presentation at the ESRI International User Conference, San Diego, CA, July 12-16, 2010).

same point in the x,y coordinate system of every other layer in the GIS. In the GIS, entities only exist if they are associated with a layer. The layers are applied to some sort of map of a type familiar within traditional cartography. Each layer is associated with a point in time. Therefore, historians can only base their analysis of change through the use of GIS on the similarity or dissimilarity between layers at different instants in time. If the representation of an entity within a particular layer varies from one instant of time to another, we must explain the change; if the representation is similar, we must explain the continuity.[70]

Space is viewed as a container (usually a 2 dimensional layer)
Entities exist only when associated to a layer
Applied primarily in traditional mapping
Raster or Vector database models
Each layer is associated to a period or point in time
Change based analysis on similarity/dissimilarity between layers at different points of time

Table 1: Main characteristics of the space dominant conceptual view

When time takes an explicit role in a representation, either with or without reference to space, the time dominance is generated and an absolute view of time is used within a model (Table 2). This *time dominant conceptual view* is effective in domains where the accuracy of temporal information makes it possible to date or order events, observations or interactions. It presents a time structure (temporal logic) and the statements about an entity are either true

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70   GIS have become so ubiquitous in contemporary life that the software has become the subject for a book in the famous "For Dummies" series; see Michael N. DeMers, *GiS for Dummies* (Hoboken, NJ: Wiley, 2009).

or false at various points in time. Al-Taha and Barrera[71] presented a first attempt to classify timedominant representations into three categories named as interval-based models, point-based models, and mixed models.

Events play an important role in these space-time representations since they are used to represent human activity, the causes and consequences of changes, or the parts of a process.[72] However, these representations have not been implemented in GIS yet. Archaeologists and geologists frequently use this form of representation to visualise change. These scientists create this surrogate to help them discover patterns in their data, and to do so using a relatively large number of factors, enhancing cognition beyond what can be accomplished without visualisations. Dynamics is understood through the analysis of change on the lineage of the events and the resulting changes in polygons.[73]

Time is viewed as a time line

Events, interactions and actions are associated to a time line

Applied in archaeology, geology and environmental sciences

Interval, point, and mixed models

Space is not an entity in itself

Event-based analysis on the lineage of events, interactions and actions.

Table 2: Main characteristics of the time dominant conceptual view

71   K. Al Taha and R. Barrera, "Identities through time", M. Ehlers and D. Steiner, eds, *Proceedings of International Workshop on Requirements for Integrated Geographic Information Systems*, (New Orleans, Enviromental Research Institute of Michigan, 1990), pp. 1-12.

72   For a valuable discussion of the concept of "event" and its relationship to the way that historians treat processes, see Ruth Mostern and Johnson, "From Named Place to Naming Event: Creating Gazetteers for History," *International Journal of Geographical Information Science* 22, no. 10 (October 2008): 1091-1108. Dr. Johnson is a Cooperating Partner of DynCoopNet.

73   Without reference to GIS, this concept was widely introduced to historians in David J. Staley, "Designing and Displaying Historical Information in the Electronic Age," *AHA Perspectives* 36, no. 9 (1998): 40-44.

By developing space-time representations based on an exploratory process approach that supports context shifting, we argue that the relative space-time view is needed for modelling the behaviour of trade networks, taking into account different text data sources, often developed independently. The relative space-time conceptual view involves the interpretation of emergent properties and the transition of changing patterns within a specific context. Table 3 summarises the main characteristics envisaged for a space-time representation based on the relative spacetime conceptual view.

Space and time are viewed as a coexistence relationship (Time Geography)
Neither time or space exists independently
Applied in studies of forms, patterns, functions, rates and diffusion
Topological based models
It may involve non-Euclidean space or linear time (e.g. fractal geometry)
Exploratory analysis of emergent properties

Table 3: Main characteristics of the relative space-time conceptual view

Choosing the configuration for a space-time representation

The two fundamental configurations to represent entities in GIS are usually known as discrete objects and continuous fields (Table 1). The *discrete object configuration* represents entities using well-defined *spatial objects* with their associated attributes.[74] The attributes that represent a spatial object include *spatial reference*

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74   Longley et al *Op. cit.*

(coordinates, feature names,[75] codes), *spatial factors* (scale, resolution, projection), *spatial measures* (length, perimeter, area, volume), *thematic information* (quantitative and qualitative values), *temporal information* (divisions of time, time in the world, time within the database), and *topological relationships* (within, contains, touches, covers). These attributes fall into three categories. First, there are invariable attributes, which cannot ever be modified or eliminated. Second, some attributes are significant for a particular version and can be updated and stored in the database. Finally, other variable attributes are not significant for a particular version and can always be updated without the necessity of creating new versions to represent each change.

Object	Point	Lines	Area	Surface
Dimensions	0	1	2	3
Examples	Telefone Pole ⭘ pole (645)	River	Country Boundary Maricopa country	Physical Terrain
	Town	Road 117 110	Property Boundary 1479 East St.	

Spatial Objects

Figure 1. Overview of possible configurations of space-time

The continuous field configuration represents entities as a finite number of variables over a surface, having each variable

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75   For historians, this task is complicated by the use of different names during different periods. For example, see Antonino González Blanco, Inmaculada García García et al, *Repertorio Alfabético de la Toponimia de la Región de Murcia* (Murcia, ES: Editorial KR, 1998).

defined at every position.[76] The continuous field view assumes that the world is a series of continuous maps or layers, each of them representing the variability of a certain attribute over the Earth's surface. There are no gaps in such layer: each location has one or another value of an attribute, e.g. "forest" or "non-forest"; "high lands" or "low lands".

  Classes function as containers in which the objects and fields can be included within them or not. Objects or fields included within the same class must have the same attributes. In order to understand what this requirement means, consider the differences between the land use classes in Figure 2. Those classes that may be updated in a new version contain fields with attributes which are significant for the versioning process. For example, in a new version, the spatial measure of a glacier or a polar ice cap may have altered from the time period of an earlier version. Those classes that do not change in subsequent versions contain fields with invariant attributes or with attributes that are not significant in the newer versions. Depending on the analytical purposes for which the scientist wishes to use a space-time representation, classes may possess different relationships. Such relationships involve *inheritance* (sometimes called generalization or sub-classification, depending on point of view), *aggregation*, or a *join* (1:m, m:n, n:1).
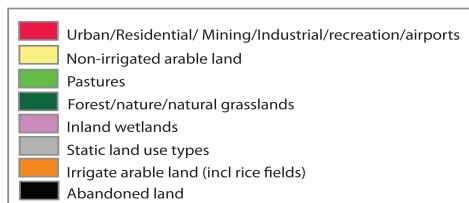
Figure 2. Land use classes

76 Longley et al. *Op. Cit.*

The choice of one configuration over another has an impact on the most effective manner of conveying the meaning of our data so that they can be understood well by others. For example, in representing population density, we might do so on the basis of countries, indicating the densities according to a set of objects (in this case a country) portrayed on a choropleth map (see Figure 3). In this representation, we provide an absolute view of space, which assumes that the population density of a country is evenly spread throughout its territory.
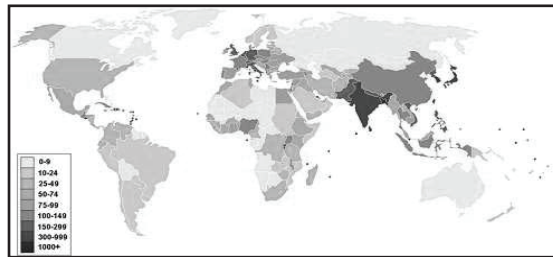
Figure 3. Absolute view representing population density by country
Source: Webster-online-dictionary.org

Although such a representation conveys important information about the situation of countries, it might not be the most effective manner of representing the way that human population density is distributed on the Earth's surface. If that were our intention, we might employ *a relative view of space*, such as that provided by the use of Voronoi cells (often called Thiessen polygons) to represent the spatial distribution of the population density data (see Figure 4). This continuous field configuration reveals something that is disguised in the absolute view: the variations of population

density within countries and along political boundaries.
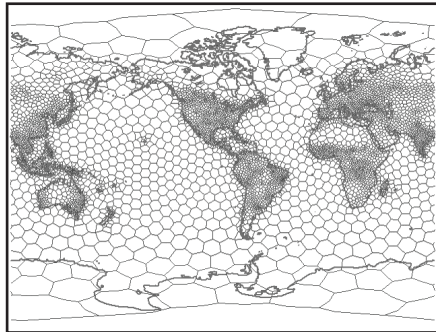
Figure 4. Relative view representing population density by Voronoi cells.
Source: publib.boulder.ibm.com

These two configurations can be implemented in GIS, and they are usually referred to vector and raster databases. Although there is a common understanding that raster databases are the implementation of the continuous field configuration, and the same occurring with vector and discrete objects, this is not actually the case. In principle, both configurations can be implemented using raster or vector databases.

Geographically-Integrated History

In proposing an exploratory process based on context shifting for the geographically-integrated history paradigm, we have distinguished a five-step process for the development of a spacetime representation:[77]

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[77] Adapted from Randall Davis, Howard Shrobe, and Peter Szolovits, "What is a Knowledge Representation?" *AI Magazine* 14, no. 1 (1993):17-33.

A surrogate of the real world: *"Finding the appropriate representation."*

A set of ontological commitments: *"Recognising about what exists and what are the relations between the concepts within a specific context."*

A fragmentary theory of intelligent reasoning: *"Identifying which inferences can be sanctioned about the behaviour of trade networks."*

A medium for efficient computation: *"Organising, storing, manipulating and recovering text* of both primary (written at the time) and *secondary* (written by historians).

A medium of human expression: *"Telling the others about the dynamics of trade networks".*

Therefore, we offer for your consideration a definition of a space-time representation and its relationship to a context, which we have adapted from Marvin Minsky.[78]

An object 'A' is a representation of object 'B' for the observer 'C' if the observer 'C' can utilise the representation 'A' in order to respond to questions that interest him about 'B' (Where: A = Representation; B = Context; C = Observer, Designer, Scientist).

Notice that in this definition the representation is not completely determined by the relative space-time conceptual view. For example, you may want to document the sources of each datum that you enter in fields associated with the different classes of objects according to different contexts that have been a-priori defined in the

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78   Adapted from Marvin L. Minsky, "Matter, Mind, and Model, in *Proceedings of IFIP Congress* 65 (Vol. 1; Washington, D.C.: Spartan Books, 1965), 45-9. Also, see Tucer I. Ören, "Directions for the Future of Modelling and Simulation: A Normative View," *International Journal of Systems Analysis, Modelling, Simulation* 1, no. 4 (1984): 293-306; Ören, Tucer I., "Model-Based Information Technology: Computer and System Theoretic Foundations," *Behavioral Science* 29, no. 3 (July 1984): 179-85.

space-time representation. Also, think about what additional data may be relevant to the way that interactions are shaped, such as social norms that may have *choreographed* interactions differently in different geographic locations.[79] The current research challenges are not related to our ability to implement such a space-time representation in a GIS, but only to our difficulty in representing the context shifting based on a relative space conceptual view, which in turn, can allow us an exploratory analysis of the dynamics of trade networks.[80]

A surrogate of the real world

A space-time representation is a complex composition of knowledge on the basis of concepts and their combinations. For example, the movement of a group of people or of water in a direction might be represented by a line with a directional arrow at the end. Instead of proceeding in a single direction, this line might define a cycle or a spiral. We could make the representation more complex by displaying direction line segments between nodes, by having our line segment divide into various branches, each of which moves in its own direction and manifests subsequent divisions, or by representing the irregularity of movement by breaking up our line segment into slashes of different lengths.

Our space-time representations result in *contexts*. The contexts possess value to the extent that they are faithful to the data

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79   We take the term "choreograph" to describe the role of social norms from Herbert Gintis, *The Bounds of Reason: Game Theory and the Unification of the Behavioral Sciences* (Princeton, NJ, and Oxford, UK: Princeton University Press, 2009), especially chap. 10.
80   For our recommendations about research lines that should be pursued to deal with this difficulty, see Monica Wachowicz and J. B. Owens, "Space-time representation of complex networks: What is next?" *GeoFocus* 9 (2009): 1-8.

and tell us something the real world from different perspectives. Visualised contexts do not reproduce reality; however, any more than the articles and books written about change and continuity reproduce the real world.[81]

The main research issue here is the scale. Scale is the relationship of the size of something in the real world and a representation of the same thing. For example, we talk about "the scale of a map" or "the scale of a model." The issue of scale takes on a particular importance when we discuss intervals of time. These intervals might be expressed in ordinal form (first time period, second time period, etc.), in discrete form (the passage of time measured in some unit, such as minutes), or in continuous form (as a flow represented by a continuous line). When we speak about *scale*, we are talking about a relative quantity.

On the other hand, granularity is the measure of the size of components or the descriptions of the concepts that make up a context. The more granular the measurement or description becomes, the more specific the information is. In order to understand granularity, think of the division of the year into months as one level of granularity. If we were then to divide the year into weeks, we would be using a greater granularity, and if we divided it into days, the granularity would increase even more.

In order to understand the relationship between *granularity* and *scale,* observe the two maps of the central area of Berlin as shown in Figure 5. The scale is identical in that a kilometre of distance in the real word is represented in each map by the same number centimetres. In this case, the scale of both maps is 1:10,000.

81   David J. Staley, *Computers, Visualization, and History: How New Technology Will Transform Our Understanding of the Past* (Armonk, NY: M. E. Sharpe, 2003).

However, one of the maps has a greater granularity in that it shows a much greater number of the streets and buildings within the area displayed than the other. Depending on the context, the greater granularity may not be more desirable because the increased number of components or elements might obscure from view those features of greatest importance given a particular context. In terms of the relationship between granularity and scale, more does not signify better!

Figure 5: Granularity versus Scale

Trade networks are complex networks that without exception are dynamic, non-linear, and selforganising in nature, and have a scale-free structure in space (e.g. from quarks, atoms, molecules, material, objects, planet, to galaxies) as well as time (e.g. from nano-seconds to galactic time). This scale-free structure reflects a hierarchical organisation of nature that is capable of framing emergent properties of complex behaviour from relatively simple micro interactions between its components over time.

The development of scale-free structures is one of the

central themes within complexity research because it goes beyond the established dualism of configurations of discrete objects versus continuous fields in GIS and moves further towards a more topological structure where relationships affect the probability of linking all components of a trade network. Therefore, a trade network is actually defined by its space-time relationships rather than by its constituent components. For example, in an economy, components might be consumers, firms and the state. Predicting whether the evolution of cooperation in trade networks might collapse, or whether dense traffic will congest, involves issues with respect to how emergence, equilibrium, and change of relationships between these components can be modelled based on a free-scale network paradigm. Applications of complex networks in modelling micro-macro phenomena are currently in demand, and a vast literature can be found in physics, biology, psychology, geography, history, economics and environmental sciences. In particular, Manson provides an interesting effort at describing the evolution of complexity research and its application in the geographical domain.[82]

Most of the theoretical research advances in developing scale-free-structures has relied on the generalisation of the Barabási-Albert model of dynamics of networks.[83] The primary research assumption is based on the use of a directed graph representation in which nodes are weighted in a hierarchical structure but not mutually connected by a high density of links. Despite the fact that some of emergent properties are being understood, directed

82   S. M. Manson, "Simplifying complexity: a review of complexity theory" *Geoforum*, 32 (2001), pp. 405-414.
83   A. L. Barabási and R. Albert, Emergence of scaling in random networks. Science 286, 509 (1999). http://arxiv.org/abs/cond-mat/9910332

graph representations do not include critical time windows and geographical constraints among their realistic assumptions. For example, the Poincaré graph has been applied to determine if a network contains a strange factor, a value or a set of values towards which the system variables tend towards over time but never quite reach.[84] However, the variables tend to moving along random different paths that are simultaneously constrained to a regular and geometric region of the graph.

A set of ontological commitments

A space-time representation is vital to provide a means for exploring the structure of text sources simultaneously with geo-information. The main research challenge is to create a spacetime representation in which the pluralism of sources can occur based on only one relevant context of the explanation. Scholars disagree about what context actually is and in what way it affects the processes of problem solving and learning in complex networks. Our first attempt was to establish the ontological commitments was largely based on the three "spaces" paradigm that has been proposed by Ernst Cassirer (1874-1945), a philosopher of the Marburg school, who describes a reasoning process as a truly dynamic activity of the mind of the human experience of spaces and time. The spaces are from an observed space through sensors and senses (interpretation), to an abstract model of space (symbolic), to a higher level of concepts incorporated in an internal and cognitive space (synthesis). Moreover, the space-time representation

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84   K. Mainzer, *Thinking in Complexity: The Complex Dynamics of Matter, Mind, and Mankind.* (New York: Springer, 1996).

combines the concepts of extensional knowledge (i.e. facts) and intentional knowledge (i.e. axioms) based on Pawlak's theory on notions of equivalence relations and deductive reasoning. Figure 6 illustrates the proposed space-time representation.
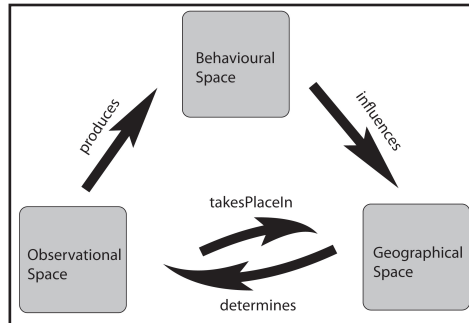
Figure 6: The multi-tier space-time representation

The Observational Space contains the classes that conceptualise the observations of the three dimensional filed in space. Observations are measurement values at every point in space, based on some measurement scale, which can be quantitative or qualitative. Besides, observations are always marked by some degree of uncertainty, which depends on the type of historical sources. On the other hand, Geographical Space is the fundamental conceptual framework where we are able to compare and quantify objects, their sizes and shapes in relation to the landscape. Finally, the behavioural space consists of individuals, groups and organisations that maintain relations through intentional (cooperative) activities based upon a more or less common set of rules, norms and values and act within the boundaries of the institutions that are derived

from it.[85] An important difference between behavioural and observational spaces is that the latter has been mostly described in geographic terms while the first has not.

Reasoning about Trade Networks

Reasoning refers to the process of making inferences or conclusions on the basis of principles, facts, or proofs. Scientists utilise reasoning about the visualised abstractions they produce for exploration, explanation, prediction, and planning.

As an example of exploration, imagine that the subject of interest is changes in trade during the century from 1890 to 1990. A scientist would begin with a question such as, what patterns of change in commerce are evident in 1890, 1909, 1927, 1968, and 1990 (t=1, t=2, t=3, t=4, Final State)? Given this description of the world at these different points of time, he or she would then model the rules that govern the observed change in the real world. Exploration of this type assumes a central importance in geographically-integrated history, which postulates that the understanding of historical processes requires an integration of place, space, and time.[86]

A geographically-integrated history scientist would move from the model resulting from exploration to a model of the explanation of the observed changes. Following the above example, he or she would ask a question such as, what factors would be relevant to the change in the distribution of commercial routes

85   F. Kleefmann, *Planning als zoekinstrument*, ('s Gravenhage, VUGA, 1984).
86   J. B. Owens, "Toward a Geographically-Integrated, Connected World History: Employing Geographic Information Systems (GIS)," *History Compass* 5, no. 6 (October 2007): 2014-2040; doi: 10.1111/j.1478-0542.2007.00476.x.

observed in historical maps over the past 100 years? Given a description of the world during a determined period of time and of the rules that govern change, the scientist would model the description of the world at different instants in time.

Because human systems and those within the geography of human action are largely complex, dynamic, and nonlinear, scientists cannot do much to predict the future with any large degree of confidence, and the confidence levels diminish rapidly as the time interval is extended ever further into the future. However, because certain aspects of geography can only be altered with great difficulty and expense –a road network for example- some types of prediction yield better results than others. The scientist would pose a question such as, if humans harvest a forest in a determined place over the next year, what changes will occur in the relations among species of flora and fauna in one year, in ten years, and in thirty years? Given a description of the world and a group of rules that govern the change, the scientist would model the world at some future moment. Geographically-integrated historians find prediction most useful as a means to test their understanding of the factors shaping some historical process that produced a result in the past. If this understanding cannot be used to portray, simulate, or predict, for example, the occurrence of the Russian Revolution of 1917, scientists have not yet developed an adequate understanding of the relevant historical processes and will know that they must undertake further exploration of available data, rethink the selected factors and the way they are scored or weighted, and enrich their explanations in order to calibrate their model to produce accurate results.

Within the limitations imposed by the nonlinear dynamics of the world, scientists can engage in more rational planning. For example, a scientist might ask a question such as, what is the optimal combination of species of flora and their spatial distribution necessary to maintain a stable population of owls in a determined area, conforming to existing regulations and necessary economic growth? Given a description of the desired state of the world in some period of time and of the rules that govern change, the scientist would model the sequence of actions that would most likely result in the state described by the question.

A medium for efficient computation

Because the space-time representations developed through the reasoning processes described above are frequently quite complicated, scientists must devote considerable attention to the nested composition of different models. By "nested", we mean that in order to make effective use of a computer-driven information system such as GIS. Moving from more computer-centred models to human-centred ones, we can have robust mathematical models nested within socioeconomic ones, which are nested within behavioural models, themselves nested within experimental models.[87] Among the many required tasks, scientists define the objects, classes, attributes, relations, events, data types, operations, temporal intervals, and identifiers. They select the rules controlling versions, the nature of change (continuous, discrete), the nature of agents, the functions and behaviour of model components, and

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[87] On this concept of nesting of models in behavioral geography, see Helen Couclelis, "A Theoretical Framework for Alternative Models of Spatial Decision and Behavior," *Annals of the Association of American Geographers* 76, no. 1 (March 1986): 95-113.

the type of queries the scientists expect to realise. Given current possibilities, they must choose between a relational database and an object-oriented one.[88] Recently, in this area, there is the development of Kantabutra's Intentionally-Linked Entities (ILE) database system.[89] Preliminary results suggest that ILE provides the means to represent complex entities, such as space-time blocks linking interactions that are frames and elements within which historical social scientists can enter pieces of information to build up stories. Moreover, ILE can serve to link interpretations to concepts and to establish a relational context establishing the meaning of a concept at different time periods, thus becoming a *conceptbase*.

A medium of human expression

Space-time representations emphasise human visual thinking, graphical data manipulation, and human computer interaction. Among the first process oriented perspectives on visualisation is DiBiase's characterisation of a 4-stage process that facilitates exploration, confirmation, synthesis, and presentation.[90] The goal of a visualisation is to stimulate a hypothesis rather than to portray a message. Information is to some extent constructed

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88   For a clear discussion of the use of the object-oriented database for spatial-temporal GIS, see Michael Goodchild, "Combining Space and Time: New Potential for Temporal GIS," in *Placing History: How Maps, Spatial Data, and GIS Are Changing Historical Scholarship*, ed. Anne Kelly Knowles (Redlands, CA: ESRI Press, 2008), 179-97. For a preliminary discussion of the use of a new database scheme, Intentionally-Linked Entities (ILE), which removes the arity restrictions of the object-oriented database, see Vitit Kantabutra *et al.*, "Using the Newly-created ILE DBMS to Better Represent Temporal and Historical GIS Data," *Transactions in GIS* 14, s1 (2010): 39-58; doi: 10.1111/j.1467-9671.2010.01222.x.

89   Vitit, Kantabutra, "A new type of database system: Intentionally-Linked Entities–a detailed suggestion for a direct way to implement the entity-relationship data model", CSREA: EEE, (2007): 258-263

90   D. DiBiase, "Visualization in the Earth Sciences", *Earth an Mineral Sciences*, vol. 59 (2, 1990), pp. 13-18.

by the user based on the visual display. A complimentary view focusing on the perceptual-cognitive process of interpreting and understanding visual displays was offered in MacEachren and Ganter.[91] Others who have adopted a process oriented approach to visualisation include Monmonier[92] and Openshaw,[93] with their ideas about use of map animation in the process of spatial analysis and Mitas[94] who emphasise the use of visualisation in the process of developing and applying complex landscape simulations and land use optimisations.

The main research challenge is to develop a framework that integrates the formalism of semiotics and cognitive studies to develop a conceptualisation of a space-time representation as a ***process*** that involves humans achieving insight by interacting with data through the use of visual displays that provide representations of historical data and of the operations that can be applied to those data.[95] From semiotics, we need *interactive tools* for understanding space-time representations of trade networks as well as how meaning is brought to these representations by their creators and users. From the study of cognition, we need *interface tools* that

91   A. M. MacEachren and J. H. Ganter, "A pattern identification approach to cartographic visuali-zation", *Cartographica*, nº 27 (2), pp. 64-81.
92   M. Monmonier, "Authoring graphic scripts: Experiences and principles", *Cartography and Geographic Information Systems*, nº 19 (4, 1992), pp. 247-260.
93   S. Openshaw, D. Waugh and A. Cross, "Some ideas about the use of map animation as a spatial analysis tool", H. M. Hearnshaw and D. J. Unwin, eds., *Visualization in GIS*, Chichester, John Wiley & Sons, 1994, pp. 131-138.
94   L. Mitas, H. Mitasova, W. M. Brown and M. Astley, "Interacting fields approach for evolving spatial phenomena: Application to erosion simulation for optimized land use", *Proceedings, Third International Conference/Worshop on Integrating GIS and Enviromental Modeling,* Santa Barbara, 1996. (http:www.ncgia.ucsb.edu/conf/SANTA_FE_CD-ROM/main.html)
95   A. M. MacEachren et alii, "Virtual Enviroments for Geogrpahic Visualization: Potential and Challenges", *Proceedings ACM Workshop on New Paradigms in Information, Visualization and Manipulation,* (Kansas City, 1999), pp. 45.

incorporate how historians conceptualise problem domains, process visual displays, and link mental schemata to actions.

Conclusions

The objectives of this paper have been to disclose the value of developing space-time representations and their relevance to modelling the dynamics of trade networks, and to propose a five-step process approach for the development of a space-time representation that supports the geographical integrated history paradigm. New space-time representations will be developed in the near future in order to support tools for historians to access, retrieve, merge, analyse complex and large data sets in an interactive and iterative way, involving visual thinking and automated information processing. The forthcoming tools will facilitate context shifting, whether this context is used for steering data mining, identifying, comparing, and analysing entities, or trying to link entities to a real-world phenomenon. The key goal is to find relationships among entities in a geographic space over time using a single transparent environment that is intuitive and supportive of the heuristics of a historian while defining a flexible, adaptive control structure for algorithmic process and graphic user interface - the ideal paradigm for geographically-integrated history.

Geo-history: Incorporation of geographic information systems into historical event studies

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Introduction: GIS and History

Since its creation, GIS has been used for solving spatial planning, environmental, geographic and social issues. Since the late 60's the first GIS were used for tasks that interrelated geographic areas and the people inhabiting them, as reflected in crime studies conducted at the police department in St. Louis, Missouri (USA) which were undertaken using a primitive GIS called SYMAP, developed by Harvard University[96]. From the late '80s on, with the advent of computers having higher capabilities and performance, GIS has further increased its use in various fields and applications, highlighting its potential for assessment of human activities and social relationships.[97] GIS also facilitate management

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[96]   David Weisburd and Tom McEwen, *Crime Mapping and Crime Prevention*, (Monsey: Criminal Justice PRess, 1997):8; Keith Harries, *Mapping Crime: Principle and Practice*,(Washington, DC: U.S. Department of Justice; Office of Justice Programs; National Institute of Justice,1999),92;.

[97]   Michael Goodchild, et al., "Toward spatially integrated social science", *International Regional Science Review*, 23(2) (2000): 139–159.

and representation of spatial data, modelling behaviour in a spatial context and interacting with temporal attributes. For this reason, GIS has attracted great interest among historians, who have large databases of events occurring in the territory. It is clear that when historians are compiling information, they are more cognisant of other issues than structuring information to be used by a GIS. For this reason, the format types in which these historical databases are initially stored are unwieldy and difficult to analyse in a GIS[98]. This inadequate structuring of historical sources and the lack of tools for discovery and management of temporal patterns are factors that increase complexity when applying geomatics tool for these studies. If the format in which historical data were originally stored is not manageable within a GIS, then it will be necessary to model them in a way they can be incorporated efficiently. For this reason different studies claim that GIS must increase their capabilities for analysis of the temporal variable.[99] In the past 20 years a variety of models to store these data types had emerged, the first one of them being the Snapshot Model[100] in which temporal information is incorporated into the spatial data model across timestamped layers, which show the different states of geographical distribution at different times without an explicit link between them. There are other models that have improved the first proposal made by the Snapshot Model; however, as it will be shown below, each has its pros and cons. Some of them may be simple to implement

98   J. B. Owens, "What Historians Want from GIS?" *GIS Best Practices: Essays on Geography and GIS*, Redlands, California: ESRI,(2008): 35-46.
99   Donna Peuquet, "Making Space for Time: Issues in Space-Time Data Representation", *GeoInformatica* 5 (1) (2001): 11-32. Stefano Spaccapietra., "Editorial: Spatio-Temporal Data Models and Languages", *GeoInformatica,* 5 (1), (2001): 5-9
100   Gail Langran and Nicholas Chrisman, "A framework for temporal geographical information systems", *Cartographica*, Vol. 25, No. 3, (1988):1-14.

with current tools, but do not provide sufficient capability for analysis, while others, much more flexible when querying, are extremely complex when implemented in software. The research work of historians can result in data repositories with hundreds or thousands of events located both geographically and temporally. But having many records in a database does not translate directly into information.[101]

GIS has been slowly incorporating the time variable in their representation and analysis capabilities[102], although its functionality in this field has aspects to be developed as yet. Queries about dates and times in which a particular event happened should give way to analysis of how an event has changed over a period of time. That is part of the objective of the recent field of spatiotemporal mining data, which aims to analyze patterns that are implicit in the data.

Talking about space-time queries in a GIS involves more than being able to design algorithms for data processing. While providing new features to analyse time and space seems to be a leap forward, the visual format in which these tools are presented is also part of the problem to be considered[103]. The database clearly does not understand natural language, and in turn knowing computer language statements is not a requirement for the end user. With this scenario, a solution in the form of graphical query interface can be the link between the GIS and consumers of geographic information; for this reason the way events that occur in time and

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101   Jiawei Han, Micheline Kamber, *Data Mining: Concepts and Techniques Second Edition*. (Morgan Kaufmann Publishers, 2006):5 22, 291-359.
102   ArcGIS Tracking Analyst, http://www.esri.es/index.asp?pagina=199 (Accessed February 27th, 2010); Google Earth Blog, http://www.gearthblog.com/blog/archives/2006/09/google_earth_4_time.html (Accessed February 27th, 2010)
103   Natalia Andrienko et al, "Exploratory spatio-temporal visualization: An analytical review", *Journal of Visual Languages & Computing* (2003) 14 (6) (12): 503-541.

space are presented, and the facility for queries have some importance.

Thus, the visual representation in this work is important and should point out that a paper or digital map is almost always the end product of a process that begins with the first collected data. However, the visual information should not be viewed only as a representation of the database, because this type of data output can be used both for visual analysis, visual thinking, and for disclosure, visual communication.[104] In the first case the map is used to generate ideas and hypotheses about the problem under study, while the second focuses more on the creation of synthesis and presentation of data to a wider audience.

Framed between these two paradigms –visual analysis and dissemination– time and its presentation in maps has been a topic of interest for many years. A classic example of these representations dates from 1861, when Joseph Minard represented the advance and retreat of Napoleon in his Russian campaign of 1812 on a map.[105]

Nowadays there is a variety of models of space-time representation: space-time slice, space-time slab, time series animation, and so on[106]. One of the most used model is the spacetime cube, where time is seen as a dimension orthogonal to the map, where past events are closer to the map and the more recent events are further away. This first model of presentation is directly based

104   Alan MacEachren, *Some Truth with Maps: A Primer on Symbolization and Design*. (Washington, DC: Association of American Geographers,1994)
105   Princeton University QED website: http://qed.princeton.edu/images/thumb/0/0e/Minard_carte_figurative.jpg/800px- Minard_carte_figurative.jpg (Accessed February 27th, 2010)
106   Alan MacEachren, *How Maps work: Representation, Visualization and Design*, (New York: The Guilford Press, 1995), 252, 254.

on the idea of Time Geography[107]. This model has been implemented in socalled Geotimes software which is available at www.oculusinfo.com.

Another important form of time representation is by means of the dynamic animation of maps through the appearance and disappearance of elements as you move across a timeline). Currently more and more commercial software is including this device, one of the pioneering works on this topic being TimeMap.[108] Both approaches have their peculiarities when analysing and presenting information; this topic will be addressed again as we explain its repercussion on our work later.

The tool being designed in this project, which is involved in "DynCoopNet", will enable historians to enquire and analyse a space-time dataset, obtaining a dynamic representation of the results. The general objective is to discover patterns of behaviour in dynamic events that shed light on historical facts with little or no verification. The next sections will deal with a presentation of the issue. Subsequently, we will show the literature sources looked up, the methodology for tool design and application to the study case. Finally the conclusions and future work will be presented.

Three Basic Problems of History-GIS Integration
Inadequate, ambiguous or incomplete data sources

As mentioned in the introduction, most data sources used by historians are designed from the start to be stored in a database,

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107   Torsten Hägerstrand, "What about people in regional science?" *Papers of the Regional Science Association*, 24, (1970):7-21
108   Ian Johnson, "Mapping the fourth dimension: the TimeMap project" *Proceedings of the Computer Applications in Archaeology Conference*, Birmingham, UK. BAR International Series (1997).

not within a GIS. One reason for this is the historical context of the data, which, in most cases, last longer than their original purpose. At the time of being collected, in most instances there were no analytic tools (computerised or not) that we would wish to apply at the present time. For this reason it is important to consider the processes that will be needed to transform the values in order to introduce them into a GIS. It is not sufficient to change the file type, but it is necessary to fill the data gaps or design a method to work with them. And finally a system has to be created to deal with ambiguous information or define a tolerance range for the tolerable historical inaccuracy within the repository to be included in the geographic information system.

Incorporing time into GIS

As answers for the question of how to incorporate time into GIS, several models have emerged. As already mentioned, the first model was the Snapshot, and then followed by other models of which a detailed reference will be made later. It should be noted, that so far no model is known to have been implemented in a comprehensive way by a GIS. Even the simplest of these models, mentioned in this paragraph, has a partial incorporation through the timeline. For this reason, added to the selection of the data model to be used, one must also consider how to implement it using currently available geomatic tools. Taking as an example the Spatio Temporal Entity Relation (STER) and the SpatioTemporal Object Oriented models, both have got a great capability to represent reality[109]; their analysis operations are fairly comprehensive and

109   Nikos Pelekis et al., "Literature review of spatio-temporal database models", The Knowledge Engineering Review 19 (2005): 235-274

they are also based on very solid of computer science foundations. However, fully operational spatiotemporal databases in which the STER model or its objectoriented counterparts were implemented are unknown.

This lack of Data Base Management Systems (DBMS) with more spatiotemporal capabilities, makes the incorporation of time into GIS more difficult, leaving two ways to address this lack. The first would be the construction of a GIS that natively supports the selected spatiotemporal model. The second would be to design and implement a software layer that expands existing capabilities for managing time and space.

Representation of time

Time is no stranger to the maps and therefore not to GIS either; as figures that change colour, shape or texture to show past, present or future events over a geographical area, time has been around for many years in both forms of representation[110]. For this reason, the difficulty time presents is not about its inclusion in the visual output of the GIS, but in finding a more versatile representation that enables a visual analysis facilitating the understanding of phenomena by experts, and also preparing the data for presentation to the general public.

Of the two models commonly used to represent time, the space-time cube, has got well known characteristics to analyse the behaviour of entities, although their level of analysis decreases as the number of objects under study is increased. This is the result of

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110   Keith Harries, *Mapping Crime: Principle and Practice*,(Washington, DC: U.S. Department of Justice; Office of Justice Programs; National Institute of Justice,1999).

the very form of the model, representing time as an orthogonal dimension on the map; despite attempts to give the impression of a third dimension, the reality is that all interaction is seen on a twodimension plane in which points that should be suspended over the map hide others that are, in theory, above or below them.

Regarding the other model, the map animation (timeline), its ability to present time in its purest form results in an interesting advantage over other approaches[111], i.e. the ability to play forward and backward on a time line and the fact that the map or objects on it change as a reaction to the user actions; it is one of the unique features of this model. However, the animation by itself does not easily respond to spatiotemporal questions or allow discovering space-time patterns implicit in data, although the animation can be stopped and notes of the time in which a particular change happened can be taken. The interactivity required to change the visual and analytic perspective is a topic yet to be developed.

What is the most efficient way for a user to perform a spatiotemporal query and see its results? This question is an example that summarizes the problem of time display in a GIS, which is a process of facilitating new visual tools for analysis and determining their effectiveness in meeting public expectations; all of this integrated in the GIS environment, which is both source and entry of data, in order to turn them into visual information.

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111   Menno-Jan Kraak et al., "Cartographic animation and legends for temporal maps: exploration and or interaction", In *Proceedings of the 18th ICA/ACI International Conference.* Stockholm, Sweden (1997):1

Bibliographic Sources

The purpose of this section is not to present a detailed state of the art of each topic, but a brief introduction to concepts used in the various stages of design of the tool for analysis and dynamic visualisation of time. A list of storage models has been made, an important point at the moment of preparing the data of historians for their incorporation into GIS. An introduction to data mining and its development to the inclusion of spatiotemporal data are exposed, presenting the basis of the tool analysis module in a later stage. As a complement to data mining are genetic algorithms, whose function is to allow the optimisation of the functions responsible for discovering implicit data patterns.

Spatiotemporal data models

The problem of time in GIS may be due to the fact that GIS and DBMS developments have followed individual and separate paths, at first only spatial data being considered, then hitting many barriers regarding the incorporation of spatiotemporal components. In the early 1990's, various studies were based on the addition of temporal capabilities in DBMS.[112] In recent years, GIS research has been focused on spatial-temporal modelling, visualisation and analysis. However, researchers of space-time models in GIS have primarily approached this topic from a conceptual and technical

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112   John Roddick and Jon Patrick, "Temporal semantics in information systems-A survey", Information systems, Vol. 17, (1992): 249-267; Abdullah Uz Tansel et al., *Temporal databases: theory, design, and implementation*, (Redwood City, Calif, Benjamin/Cummings series on database systems and applications Benjamin/ Cummings Pub. Co.1993).

perspective and model implementation[113].

Many GIS data models have been proposed to incorporate temporal information into spatial databases. Temporal information is generally associated with time reflected in individual layers such as models that use the space-time cube[114], the Snapshot Model,[115] or individual spatial objects such as the Space-Time Composite Model and base state with amendments[116]. Most recent studies in this line advocate for modelling spatiotemporal phenomena via events: event-oriented approach,[117] event-based spatial temporal data-ESTDM,[118] processes, the evolution of geographic features/objects or activities.[119] Other studies imply advances in spatiotemporal database systems such as Intentionally-Linked Entities (ILE) that provides the means to represent complex entities and establish a relational context.[120]

Great efforts have been made to build geographic databases

113   Gail Langran, *Time in Geographic Information Systems*, (Taylor & Francis, 1992); Donna Peuquet, *Representations of Space and Time.* (New York: Guilford Publications 2002).

114   Hägerstrand, 197026

115   Marc Armstrong, "Temporality in spatial databases", *Proceedings, GIS/LIS'88,* San Antonio, Texas, USA, Vol. 2, (1988): 880-889

116   Gail Langran and Nichoas Chrisman, "A framework for temporal geographical information systems", *Cartographica*, Vol. 25, No. 3, (1988): 1-14.

117   Christophe Claramunt and Marius Theriault "Managing time in GIS: an event oriented approach", In: *Recent Advances on Temporal Databases*, Eds.: Clifford, J. and A., Tuzhilin, Zurich: Springer-Verlag, Switzerland, (1995): 23-42

118   Donna Peuquet and Niu Duan, "An event-based spatiotemporal data model (ESTDM) for temporal analysis of geographical data", *International Journal of Geographical Information Systems,* Vol. 9, (1995): 7-24; Jun Chen and Jie Jiang, "An event-based approach to spatio-temporal data modeling in land subdivision systems", *Geoinformatica.* 2, (1998): 387-402

119   May Yuan, "Temporal GIS and spatio-temporal modeling", *Proceedings, Third International Conference on Integrating GIS and Environmental Modeling,* NCGIA, CDROM. Santa Fe, New Mexico, USA (1996); Lynn Usery, "A feature-based geographic information system model", *Phtogrammetric Engineering &Remote Sensing.* 62, (1996):833-838; Monica Wachowicz, *Object-oriented design for temporal GIS.* (London: Taylor & Francis 1999); Wang and Chen, "A spatio-temporal data model for activity-based transport demand modeling" International Journal of Geographic Information Science,15, (2001):561-585

120   Vitit Kantabutra, "A new type of database system: Intentionally-Linked Entities–a detailed suggestion for a direct way to implement the entity-relationship data model", *CSREA: EEE,* (2007): 258-263

and a prototype intended for space-time data, such as the conceptual and its implementation issues for certain applications; however there is no overall framework that can be extended to any application.[121] But the big question is how GIS can understand the temporal concept and manage time-related information? Some theories have been suggested attempting to simulate human understanding of time and spatiotemporal reasoning.[122] Other approaches have used the fuzzy set theory.[123] The fuzzy model explains the uncertainty in geographical data and it is used in dealing with classification of specific localization of objects. Some of the studies are based on fuzzy for modelling time in GIS.[124]

Data mining

In a simple way, it may be said that data mining consists in the extraction of implicit information from a large amount of data. Generally these methods can be divided into two categories: classification and prediction. The first characterises the data key attributes, while the latter is used to analyse the future behaviour based on known facts. Regarding classification methods there is

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121   Donna Peuquet, "Making Space for Time: Issues in Space-Time Data Representation", *GeoInformatica* 5 (1) (2001): 11-32.

122   James Allen, "Toward a general theory of action and time", *Artificial Intelligence,* 23 (2), (1984): 123- 154; Antony Galton, Temporal logics and their application, (San Diego. Ed. Academic Press 1987); Andrew Frank, *Different types of "Times" in GIS*, Egenhofer MJ, Golledge RG (eds) *Spatial and temporal reasoning in Geographic Information Systems*, New York-Oxford: Oxford University Press1998): 40-62.

123   Lofti Zadeh, "Fuzzy sets". Information and Control, 8(1965): 338-353

124   Fangju Wang et al., "Fuzzy information representation and processing in conventional GIS software: database design and applications", *Int. Jl. Geographical Information Systems* 4, (1990): 261–283; Dieter Pfoser and Nectaria Tryfona "Fuzziness and Uncertainty in Spatiotemporal Applications", *Lecture Notes In Computer Science;* Vol. 2151; *Proceedings of the 5th East European Conference on Advances in Databases and Information Systems* (2001): 112 – 126; Suzana Dragicevic and Danielle Marceau, "A fuzzy logic approach for modeling time in GIS", *International Journal of Geographic Information Science*, vol. 14, no. 3, (2000): 225-245.

a wide range: Decision Trees Induction, Bayesian classification, classification IF-THEN rules, Backpropagation (learning algorithm based on neural networks), Support Vector Machines (classification by association rules analysis), Lazy Learners (learning from neighbours), Genetic Algorithms (attempt to incorporate ideas from natural evolution), rough set approach (used to discover the structural relationships within inaccurate previously unprocessed data), Fuzzy Set Approaches (instead of applying precise rules, choice of a fuzzy classification).

As data mining became better known, entities with spatial and temporal components were included in its scope, creating new specialisations in implicit knowledge discovery. In the spatial field, data mining is the process of discovering previously unknown patterns in large spatial datasets[125]. In the temporal field, data mining focuses on analysing large sequential datasets, which by their nature are arranged in relation to an index, in this case time.[126]

Spatiotemporal data mining arises from the union of the two previous approaches, whose aim is to reveal the spatial and temporal relationships in the data.[127] This combination of approaches has its own techniques. The most relevant techniques include: discovery of spatiotemporal associations, generalisations, time and space, space-time clusters, etc[128]. In order to provide our tool with these capabilities, we have decided to take a first approach in which we will design a customised Decision Trees Induction and

125   Shashi Shekhar et al., *Spatial Data mining, Data Mining and Knowledge Discovery Handbook*, (Springer US, 2005): Chapter 39

126   Srivatsan Laxman and P.S. Sastry, "A survey of temporal data mining", Sādhanā Acad Proc Eng Sci 31,(2006): 173–198

127   Xiaoba Yao, "Research issues in spatio-temporal data mining", presented at UCGIS workshop on Geospatial Visualization and Knowledge Discovery, Lansdowne,Virginia. 2003.

128   Harvey J . Miller and Jiawei Han, "*Geographic data mining and knowledge discovery*", & Francis Inc, 29 West 35th Street, New York, (2001): pp 35.

Support Vector Machines to give support for temporal and spatial components of the data in our study case about transatlantic slave trade.

Genetic Algorithm

The basic idea behind the so-called genetic algorithms is to test a myriad of possible solutions to a problem that initially one does not know how to deal with. The source of these solutions comes from what is called initial population (set of solutions), which contains a first approximation of what is probably the answer to the problem. Based on this initial population, the suitability of each individual to solve the problem is tested, and depending on its success, some solutions (individuals) are discarded and the most successful are replicated through operations that impregnate them with small changes called mutations, which are used to generate a second population and restart the process again.

The term genetic algorithm was coined by J H Holland in his publication made in 1975 under the title "Adaptation in Natural and Artificial Systems". Currently, genetic algorithms are part of a much broader field known as evolutionary algorithms, which are grouped in different branches such as evolutionary programming, artificial life, classification systems, genetic programming and more recently the concept of evolutionary hardware. Because of the way genetic algorithms work, they are used mostly in optimisation problems where one seeks to maximize the value of a variable while minimizing the value of a second one. Applied to the study case selected, it will consist in the optimisation of values that

will allow classifying the different movement patterns of vessels through the different areas where the slave trade took place. The configuration of these values could be done manually, but trying all possible solutions would result in a very long-term work that could be done much faster and more efficiently by genetic algorithms.

Design of a spatiotemporal analysis tool
Slave trade database as data source

The source of data chosen is based on a data set regarding the transatlantic slave trade. This data set is freely open to the public on the www.slavevoyages.org website[129]. The data are compiled by an international group of researchers associated with the University of Emory and are very well suited to the study to be undertaken. It comprises a register of around 35,000 voyages made by slave traders between 1519 and 1867, in which more than 270 aspects of the voyages are specified (the name of each ship, the ports where they stopped, the number of slaves embarked and disembarked, the duration of the voyage, the destination of each ship, etc.) which will allow spatiotemporal analysis of the behaviour of these ships and perform different visual representations of events.

The format of the information in MS ExcelTM consists of a single table of 274 columns and 35,000 rows, which is not very practical for the intended purpose. It was therefore necessary to transform the structure using database normalisation rules. We then proceeded to carry out an exhaustive revision of every column to try to understand the implicit relationships between them and

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129   Cf. David Eltis & David Richardson, coords., *Atlas of the Transatlantic Slave Trade,* (New Haven, 2010).

to identify the entities that would later form tables in the database.

These entities were far from uniformly expressed. Also, it must be stressed that the resulting structure must be focused on appropriate storage and on facilitating future spatiotemporal queries. A fragment of the normalised model in UML (Unified Modelling Language) is shown below (Figure 1).
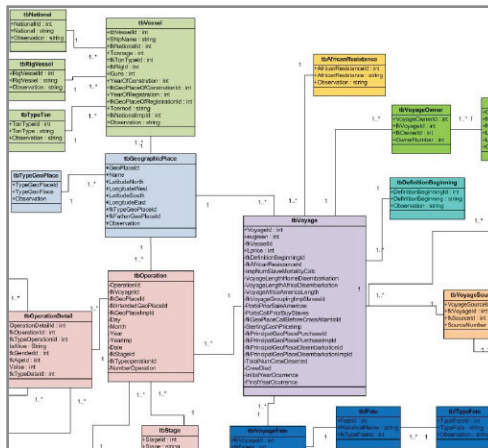
Figure 1. Fragment of slave trade database mode of the Conceptual Model in UML. The colours indicate the different parts in which the database can be analysed (Vessel, Geographic place, Operation, Fate, African resistance, Owner, Captain, Voyage and Source). This is the result of normalising the MS ExcelTM worksheet described above.

That was the design and implementation of a software tool capable of understanding the rules of normalisation[130] of

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130   Clare Churcher, *Beginning Database Design*, (Apress, 2009): 146-155.

the relational database, applying them to a particular dataset, and while moving information from one place to another, it was necessary to review the consistency and integrity of what was being transferred. We had to avoid the introduction of redundant information about the ports, ships names, captains' names and owners' names, to mention a few values. Cleansing before starting the data introduction was needed and it had to be monitored after being admitted, in order for the new database not to contain duplicate values in form or meaning.

At this point of the research work, the tool has entered a sufficient number of trips to start the prototype test. The modularity obtained from the object-oriented design[131], will bring about the benefit of some degree of reuse of the tool if it was to be applied to similar cases.The structure of the normalised database sorts out the main entities studied by historians who had created the MS ExcelTM sheet. However, this is only the starting point of any computer application. The next steps consisted of the Use Cases and design class model that would provide the functionality.

Use cases and classes model

In parallel with the analysis of the table that originally contained the data, we began to model the use cases. These use cases had to reflect the requirements that the prototype was to fulfil, specifying in writing and graphic form the ideas that motivate the creation of this application. The definition of each of the modules to be designed was recorded in this model (Figure 2), which is divided into eight use cases, covering the editing and query components

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131   Grady Booch et al.,: *Object-Oriented Analysis and Design with Applications Third Edition*, (Pearson Education, Inc 2007):54-56

with graphical output in both cases (Table 1).
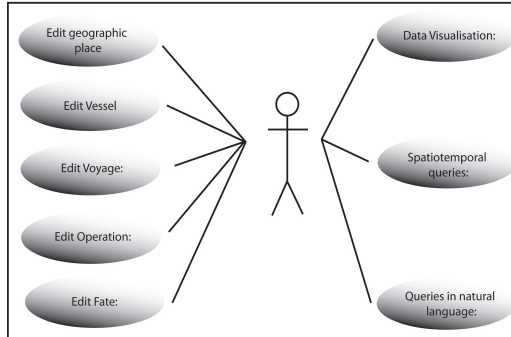
Figure 2. Use Case Diagram. Graphic definition of the requirements of the designed tool

Entity	Description
Edit geographic place	**Edit geographic place:** Each voyage is made up of a series of ports or regions visited in the course of that voyage. This module was designed to edit the information corresponding to these entities.
Edit Vessel	**Edit Vessel:** Allows the editing of the characteristics of a ship (name, type, nationality, tonnage, year and place of construction, etc.)
Edit Voyage:	**Edit Voyage:** Each voyage is an entity composed of various characteristics: the reason for the voyage, the year it took place, the time that passed between its various stages, etc. This module allows the creation of the object "voyage", which brings together the information of all of the other modules.
Edit Operation:	**Edit Operation:** The main information in this module regards the embarking of slaves in each of the African ports and their disembarking in American ports.

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Edit Fate:	**Edit Fate:** Using this module one can record or query the final result of a voyage: whether it successfully arrived to its return port, whether it was captured by pirates, or whether there was a revolt on board after the embarking of the slaves.
Data Visualisation:	**Data Visualisation**: this corresponds to the dynamic representation of these data on a map; one can also input and query data using this module.
Spatiotemporal queries:	**Spatiotemporal queries:** The main function of this module is to allow queries to be input directly on a map regarding events that took place there during a particular period of time.
Queries in natural language:	**Queries in natural language:** The objective here is to allow complex spatiotemporal queries to be written. This module allows both the inputting of SQL queries and queries using temporal expressions written in Spanish. In order to avoid queries needing comparative operator and Boolean logic such as: Select * From Table Where Fecha1 <= 10/May/1809 AND Fecha1 >= 20/Jul/1817 the module will allow these filters to be substituted by temporal expressions in Spanish (below translated into English), which are much more usable by a much larger number of users: Select * From Table Where "Between 10 May 1809 and 20 July 1817"

Table 1. Use cases description

Taking as a starting point the requirements defined in the use cases (Figure 2), we continued with the design of the classes to satisfy them. Initially we reused the design of the database, in which certain defined properties of the classes were found. However, these properties were entirely focused on the persistence of the data, such that in order to provide the dynamics required for the future visualisation and the spatiotemporal query capability, we had to incorporate new properties and methods.
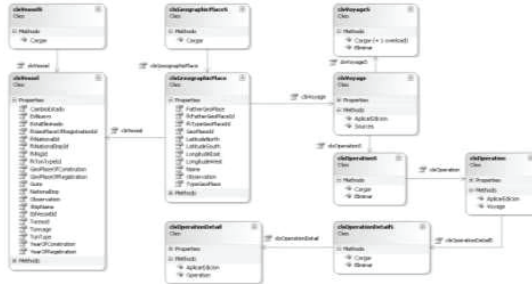
Figure 3. Fragment of class diagram

Figure 4 shows the class clsVessel which has a number of methods that illustrate more clearly how the discovery of knowledge will be present in this software layer. Methods: Captains, GeographicPlaces, Owners, Voyages, involve the temporal variable in each of their executions. A vessel could have throughout its life one or more captains, one or more owners, pass through multiple ports and / or participate in one or more voyages. The complexity of these temporal and spatiotemporal queries is hidden in the methods of this and other classes.
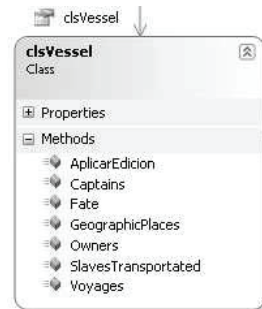
Figure 4. Class clsVessel. The methods will provide support for data mining

Spatiotemporal queries

In this context, one objective within the framework of the DynCoopNet project is to design a user interface that allows historians asking simple questions based on a number of variable parameters, for example: *object, location, time, state, quantity and logic operators* (Table 2).

OBJECT	LOCATION	TIME	STATE	QUANTITY	OPERATOR
What?	Where?	When?	How?	Where?	OR
Vessel	Here	Before	Good	A little	AND
Slave	Near	Today	Bad	Much	NOT
Port	Far	Later	Regular	Quite	XOR
Route	Around	Always	Best	More	….
….	….	Never	Worse	Less	
		Still	….	All	
		Between		Nothing	
		….		….	

Table 2. Example of scheme of user interface based on a set of parameters variation

In this project we are working towards developing simple user interfaces manageable by historians in which one can create a series of coherent questions with all of the possibilities that the

implemented GIS database offers. For example, we might ask *How many ships travelled near Cuba between 1750 and 1800, how many slaves were they carrying and what was the state of the slaves and what was their cargo and the state of the slaves carried in each of these ships*? If we look at Table 1, we would use the following parameters: vessel (object), Cuba (location), between 1750 and 1800 (time) and one could also define the state of the slaves according to the mortality rate (state) and summarize the number of slaves transported on each of the ships (quantity).

Based on an incremental iterative model of the classes, in which each of the design stages receives feedback from each implementation undertaken, this model has been gradually refined to be able to respond to alphanumeric and visual queries.

The classes are behind each of the interfaces which have been designed, bringing life to the application. Each button, grid or entity which represents the movement of a ship on the map is controlled by an object which serves as an intermediary layer between the graphic interface and the database where the data is stored and where it is extracted from (Figure 5). However, the classes are not only responsible for the tasks of inputting and editing the information. They also provide the answers to the spatiotemporal queries which are the basis of this application (Figure 6).
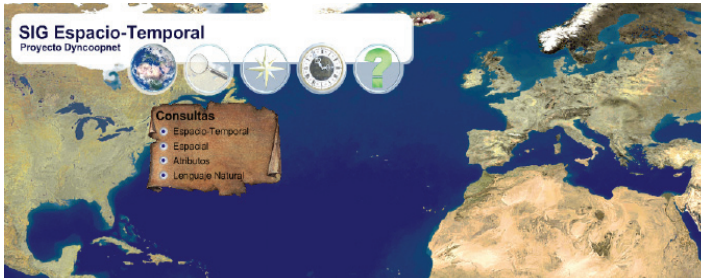
Figure 5. Design of the user interface. Behind the buttons or menus, there
are classes providing their functionality to the end user

Spatiotemporal queries test all parts of the tool, from the
database to the logic encapsulated in the classes. Being able to
respond to a requirement, which in natural language would be
expressed as: "Display all ships captured on the way to Cuba from
1750 to 1800" involves (a) spatially filtering the voyages or ships
with Cuba as their destination, (b) temporally filtering the voyages
in the date range, (c) filtering the voyages by destination and lastly
crossreferencing these three filters to identify the result of the
query.
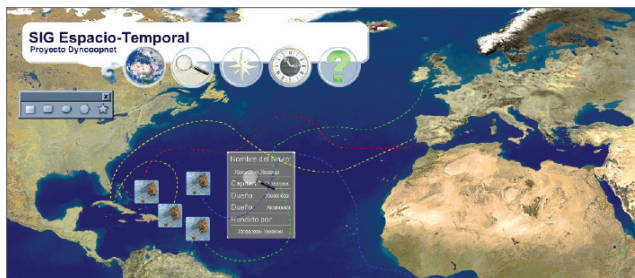
Figure 6. Design of the visual result of the spatiotemporal query about the
vessels captured in Cuba during the period 1750-1800

The query above could be approached from various starting points: from the Voyages, from the Ships of from the geographic Places. One could begin filtering the voyages that took place during that period (1750-1800), although there exists the option of filtering first by geographic place – Cuba in this case – to identify the ships destined there. And lastly one could begin by filtering by the fate of the ships and then go ahead with the other steps.

The design process took into account that the user should be able to approach the query from any of the different points of view described above and that, above all, the functionality encapsulated in each one should complement all the other related classes, as we have seen in the case of the *classes clsVessel, clsGeographicPlace and clsVoyage*. The number of queries will continue expanding as the design is implemented and the prototype is tested, feeding back into the system information received from users, programmers and researchers.
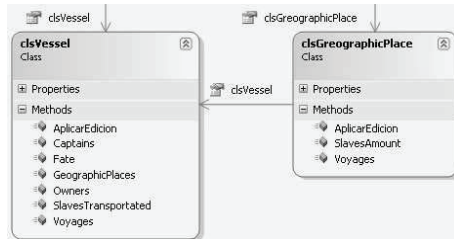
Figure 7. Classes Vessel and GeographicPlace. The clsVessel class has three methods relevant to answer the query: Fate, GeographicPlaces and Voyages and clsGeographicPlace has one, Voyages. Together these four methods show the inter-relationship that the classes have in order to tackle complex spatiotemporal questions.

Spatiotemporal data mining

a. Preparing the knowledge base expansion

Once the data to be analysed have been selected, the user has to identify the table columns (attributes) that might be implicitly related in order to have the option of extending the knowledge base in case data mining does not provide results with the current attributes. In our study case a sample of 1,200 records containing information on travels departing from Spain has been taken. One way to anticipate implicit relationships that data mining could not detect by itself would be by selecting a Start-date field and an End-date field. Subtracting one from the other results in a new attribute: Duration. This new attribute would facilitate the discovery of patterns in a data re-analysis.

b. Selection of Data mining techniques

Two techniques, decision trees and association rules will be applied in our study case. Decision trees allow the user exploring the information contained in the database through a classification process. After selecting attributes, researchers could determine which one is, for example, the most significant journey that departed from Spain and returned successfully, or what were the characteristics of ports whose attendance was greater than a certain number of ships per year. Besides, considering the time as an attribute, the characteristics that allowed the boats departing from Spain again successfully in certain periods of time may be identified or which features become attractive for some ports at

certain times.

The association rules will guide the user in spatiotemporal patterns searching. As each voyage generates a trajectory through the various ports through which the vessel transits, the geographic places are passed over in some order at certain times, and while not present in the database, this tour has duration. The combination of these attributes produces a spatiotemporal pattern in every sense of the word, because each of these patterns can be distinguished from the others, considering spatial and temporal aspects. For example, in the case of two ships that travel through the same route and one makes the journey in half the time than the other, although the trajectory is spatially identical, the discrepancy in the time variable is clearly distinguishable. However, both the patterns and the characteristics of the different entities stored in the database will ultimately be assessed by researchers using the module that will implement genetic algorithms.

c. Using genetic algorithms in result evaluation

The application of data mining on the sample will generate a set of classifications and patterns. The decision about the relevance of each will depend on the researcher using the tool. However, the configuration of certain parameters is a difficult optimisation task in which the user could benefit from the use of genetic algorithms. A couple of our reasons for choosing genetic algorithms rely on the ability they have based on an initial population, a set of rules and a goal to reach; they will reconfigure themselves until they find the optimal solution. Another advantage is their usefulness and usability for end users because they do not need new computer

skills to monitor the progress of the algorithms.

As mentioned in the previous step, in determining what constitutes a spatiotemporal pattern of trajectories, time and space should be considered. If the duration of a tour through some ports is specified in a very rigid manner (+/ - 1 day), there will be an overwhelming number of patterns. On the contrary, when the range is very flexible useful information could be hidden behind a group of data. For this reason an optimisation process in search of values is what gives the best result. Our proposal is to help the user with genetic algorithms that facilitate the selection from a pattern set. The starting point will be a set of patterns considered suitable; the algorithms will be able to mute and to present new options from which the user would select the most suitable pattern, thus achieving an approximation based on resulting patterns instead of a long manual calibration of classification or association parameters.

d. Knowledge base expansion

Sometimes it is not possible to find classifications or patterns relevant to a certain research study. As mentioned above, having a column with the start date and another with the end date do not imply knowledge of the event lifespan; if a lifespan column is lacking, then it is not possible to use knowledge discovery techniques. For this reason, once the information that could be discovered in a dataset seems to have been exhausted, the user could proceed to expand the attribute number of the dataset in order to re-analyze it in a new light.

The expansion is not a random process; it will be based on

what the researcher has defined in issue 1. The user may append columns about voyage duration, distance travelled, and from these new attributes and new information could be inferred, as is the case of the average speed, which would be the result of the division of two attributes that were not present at the beginning (duration and distance travelled). After data re-analysis the user could choose to create new attributes based on the results of the previous analysis, then re-re-analyse again, see the results and create new derivative attributes and so on. It is a recursive process that could expand the dataset as long as the user needs.

e. Dynamic visualisation

The spatiotemporal GIS prototype has been designed to work in a web environment, to facilitate the dissemination and scope of the project to anyone connected via the Internet. The spatial data are typically visualized using maps; this is known as "static" representation. However, the spatiotemporal data, as historical data, require advanced techniques to achieve a dynamic visualisation such as symbology in space-time maps and cartographic animation. Dynamic visualisation tools in a GIS environment can be very effective in the analysis and representation of complex data in a wide range of disciplines. At present, the project is in the process of designing a set of interactive tools integrated in a web application consisting of a time manager, analysis and animation tools. The time manager is connected to a map display, so the user can interact with the time and visualise the events selected in a time period or instant view (Figure 8). As a result this application should be a helpful tool to represent the past historical events occurring in

selected locations with smooth timing to let users understand the changes of historical sites clearly and discover behaviour patterns. In addition, it allows querying spatiotemporal data and displaying the historical results accurately and quickly.

Figure 8. Design of the dynamic visualisation is one of the main functionalities that this tool will provide to the end user. Using the data stored in the database, an animated representation will be created of a single or multiple voyages and their final fates

Conclusions and future work

Examination of data through space and time is a crucial task for historians, because this type of analysis leads to an understanding of the motives that triggered the occurrence of past events or processes. Nowadays, few commercial programs have

developed GIS capabilities to incorporate the temporal component. Advances have been mainly directed to the design of databases that support thematic components, space and time, but that is only the first stage of the process.

The management of these types of data and the analysis that is applied to them, like changes in a phenomenon over time (interpolation and uncertainty assessment) represent a very significant step in this type of research. Being able to discover patterns of behaviour, flow of time-space activities, routes, etc. and to predict their future development continues to drive our research. This study hopes to provide useful information for building more robust theories about the interaction of dynamic entities in different settings and space-time contexts. After the designing stage the implementation inside a GIS will proceed. First, the model will be implemented in commercial software, in view of the ease of customisation offered in ArcGISTM. Later, when the capabilities of the design have been proved, the model will be migrated to OpenSource GIS (gvSIG) with the aim of reaching a wider audience. The next step will consist in a process of validation and usability, making the appropriate tests with end users, historians and interested researchers, in order to analyse the user interface, the usability, the tool performance on different platforms and to suggest improvements in individual cases.

Commercial flows and transference patterns between Iberian empires (16th-17th. centuries)

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Theoretical framework

It is quite usual that the analysis of European empires in the Early Modern Age is focused on central power strategies and imperial rivalries. On the contrary, our perception is that a large number of individuals or groups contributed extensively to the development of overseas expansion dynamics, sometimes to an even greater extent than the central power or central government did. In this chapter, based on the study of Iberian maritime expansion, we sustain that a widespread co-operation was in place and was able to link and to connect Portuguese and Spanish overseas territories through self-organized networks. In particular when we look at the performances which were developed in the Atlantic, during the Early Modern Period, individual initiatives were crucial to those achievements.

This approach is related with the multi-disciplinary

collaborative research project, DynCoopNet.[132] The theoretical outline of this project contends that between the fifteenth and eighteenth centuries the world economy was increasingly characterised by widespread collaboration which went beyond the boundaries of countries and continents; such step was possible thanks to new means of global communication as well as to the building up of formal and most of all of informal networks that were often multinational. Among the primary assumptions we intend to put forward and study, there are a few-ones that can be emphasised:

1. Co-operation linked several self-organized networks.

2. The world economy became, at this period, a dynamic, open, complex, and non-linear system.

The history of any place within this world cannot be understood without examining how it was connected to other locations and to the system as a whole.

There are variations among sub-systems which set up a view or understanding (explain or sample) of the system's complexity.

Some of these theoretical premises may have notorious potential implications for the analysis of our subject. According to DynCoopNet, co-operation-based networks acted as a source for the creativity and innovation necessary to respond in a flexible manner to the disruptions in commodity, information, and capital flows; thus very active formal and informal networks constituted either by institutions and individual agents, respectively, were key-factors in the maintenance of the system.

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132   DynCoopNet (Dynamic Complexity of Cooperation-Based Self-Organizing Commercial Networks in the First Global Age) submitted to the ESF (European Science Foundation) EUROCORES (European Collaborative Research Programme) "The Evolution of Cooperation and Trading" (TECT).

These ideas present themselves as a major tool to re-evaluate worldwide dynamics from a new point of view, that is centred on individuals and in the way they were connected with each other through networks. We will try to apply and discuss these assumptions focusing on the Iberian Peninsula overseas expansion case.

This theoretical approach requires the use of concepts and methodologies frequently imported from other sciences rather than History. We could mention the concept of networks; the concept of cooperation or, in the methodological field, the social network analysis and the agent-based analysis methodology. Abundant secondary literature has been produced on these subjects by a wide range of disciplines which run from sociology to economy, mathematics, and anthropology.[133]

"Social network theory views social relationships in terms of nodes and ties. Nodes are the individual actors within the networks, and ties are the relationships between the actors. There

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[133]   For network theories, see for instance, the works of Duncan J. Watts, *The Structure and Dynamics of Networks* (Princeton: Princeton University Press, 2006); Linton C. Freeman, *The Development of Social Network Analysis: A Study in the Sociology of Science* (Vancouver: Empirical Press, 2004); Alan Latham, 'Retheorizing the Scale of Globalization: Topologies, Actor-Networks, and Cosmopolitanism', in *Geographies of Power, Placing the Scale*, ed. Andrew Herod, and Melissa W. Wright, (Oxford: Blackwell, 2002), 115-144; *Models and Methods in Social Network Analysis*, ed. Peter Carrington, John J. Scott and Stanley Wasserman (Cambridge: Cambridge University Press, 2005); David Knoke and Song Yang, *Social Network Analysis*, (2nd ed. London: Sage , 2008); *Spinning the Commercial Web: International Trade, Merchants, and Commercial Cities*, c. 1640-1939, ed. Margrit S. Beerbühl and Jörg Vögele (Frankfurt am Maim: Peter Lang, 2004), 11-23; Albert-László Barabási, *Linked: The New Science of Networks* (Cambridge: Perseus, 2002). In what concerns the Economy approach on this subject see Gernot Grabher, 'Trading Routes, Bypasses, and Risky Intersections: Mapping the Travels of "Networks" between Economic Sociology and Economic Geography', *Progress in Human Geography*, 30 (2006), 163-189; Russell Hill and Robin I. M. Dunbar, "Social Network Size in Humans" *Human Nature* 14, No. 1 (2002), 53–72; Matthew O. Jackson, "A Strategic Model of Social and Economic Networks", *Journal of Economic Theory*, 71 (2003), 44–74. In what refers the concept of cooperation and the models of analysis, cf. the accurate panorama provided by the international conference E*volution of Cooperation – Models and Theories* (Luxemburg, 15-18 September 2009)

can be many kinds of ties between the nodes. In its most simple form, a social network is a map of all of the relevant ties between the nodes that are being studied".[134]

Applying this broad definition to our case study, which intends to analyse the presence and action of networks in Iberian empires[135], those could be, and frequently are, both formal and informal, the former being constituted by institutions. This goes, for example, for the administrative and financial networks established in the territories under Portuguese rule whether with the status of factories on the West Coast of Africa; captaincies in the Atlantic Archipelagos; General Government in Brazil, or in the form of a state, such as in the State of India. Those are related to formal and institutional networks which come to include internal networks based on individuals.

Among these formal and institutional colonial networks, we have to consider, in the first place, all the administrative, financial and military structures which represented the crown. They included a wide range of officers: viceroys (in the East), governors (in Brazil and India), ambassadors (in Africa and the East), judges, bailiffs, captains, tax collectors, purveyors, notary officers, accountants, etc. Furthermore, we must keep in mind the institutional frame-

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134   John Scott, *Social Network Analysis: A handbook* (London: Sage, 2000).
135   This is another dual concept that should be analysed in a more detailed approach. Firstly, because we must clarify what variables we have to deal-with in order to identify and defined an empire in the context under study; in the second place because there was hardly such thing of an Iberian empire, even during the political union between Portugal and Spain during Philippe II, III and IV of Spain (1580-1640). Furthermore, the models and frameworks of Portuguese and Castilian overseas empires are quite different and need to be understood and studied in different basis. This will have to be, however, object of another paper and theoretical development. For practical reasons, we'll use in this paper some apparently accepted concepts, as the one of empire, departing from the study of the Portuguese case and analysing how the strategies and models put in place by the Portuguese affect and project themselves on the Castilian empire, modelling it, as well, by the performances and actions of Portuguese agents.

work provided by the missionaries: Franciscans, Jesuits, Dominicans, Benedictines, or even the ecclesiastical networks that were kept by the structures of the overseas parishes, which role cannot be forgotten. The Inquisition acting overseas, sometimes depending on regulations sent from Lisbon, presents itself as a network as can be acknowledge through the information transference it performed.

Still at an institutional level, we have to consider as well the links established between municipalities, basic cells of political and administrative local power, which reproduced the same model of the Portuguese metropolitan territory. In the same line of thought, the framework provided by the *Misericordia* Houses[136] in the Portuguese colonial settlements should be taken into account. Ruled by the same status, each one was almost a copy of the other, all of them based on the mother-house of *Misericordia* in Lisbon. These institutions provided not only spiritual and social assistance to Portuguese settlers and their families, and inheritors, but acted as a new way of conveying news, goods and money from Miseridordia to Misericordia until they reached the most eccentric place in Portugal. Intense flows of news, goods, fortunes, last-wills and additional private documentation were cared and dispatched by this institutional framework, running side by side with the official papers, and frequently in a more efficient way than if they were mailed through the administration strings.

Besides this setup, based on formal and institutionalized networks, ruled by formal powers of the crown or of the Catholic Church, we ought moreover to consider the individual connections

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136   Misericordias were civil confraternities introduced in Portugal by the queen Leonor, at the end of the fifteenth-century (circa 1498). As we stated, the overseas Misericordias duplicated and emulated the organization of their metropolitan counterparts.

between agents overseas; these are more complex networks, which become increasingly difficult to identify and study. Three main types of agents can be recognized: seamen, covering an entire range of categories from sailors to captains; settlers and labour migrants; merchants and adventurers. The abovementioned complexity in the identification of these networks comes from the fact that since pluriactivity/multi-activity seemed to prevail among these groups, at a first sight it would be acceptable not to establish deep boundaries between them.

However, if we look carefully, they all are frequently members of informal and sometimes uncontrolled networks, which emerge, disappear, reformulate and interact according to casual, contextual and sometimes regardless of the customary legal patterns. In this sense, the concepts and the methodologies of social networks are not always able to fully understand the performances of these agents. Instead, we have to apply, in its analysis, the actor network theory principles[137] or, more accurately, those of the agent-based modelling.[138]

Agent based modelling is required when individual behaviour is non linear; agent interactions are heterogeneous and

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137   About actor-network theory see, among others, Saonee Serker and Anna Sidorova, "Actor-Networks and Business Process Change Failure: An Interpretive Case Study," *Journal of Management Information Systems* (JMIS), 23, No. 1 (Summer 2006), 51-86; *Actor-Network Theory and After*, ed. John Law and John Hassard (Oxford: Blackwell, 1999); *The structure and dynamics of networks*, ed Mark Newman, Albert-László Barabási, and Duncan J. Watts (New Jersey and Woodstock: Princeton University Press, 2006); Bruno Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory* (Oxford: Oxford University Press, 2005); Jonathan Murdoch, 'The Spaces of Actor-Network Theory', *Geoforum*, 29 (1998), 357-374.

138   Caroline Haythornthwaite, "Social network analysis: An approach and technique for the study of information exchange". *Library and Information Science Research*, 18, No. 4 (1996), 323-342: 323-342, and Stanley Wasserman and Katherine Faust, *Social Network Analysis. Methods and Applications*, (New York: Cambridge University Press, 1994).

middling will not work, because the system is generally unstable[139] - which are all conditions recognised in the historical reality under study.

One of the main theoretical assumptions of this theory is that departing from the position of the individual in a network and looking at his connections, one can be able to characterize and understand the system, e.g., to understand the functioning of a given social phenomenon. Following Wasserman and Faust, it is possible to accept that "network models conceptualize structures (social, economic and so forth) as lasting patterns of relations among authors".[140] It means that the unit of analysis is not, in fact, the individual, but the entity consisting of an assortment of individuals and the existing links between them.[141]

The use of agent-based network theory implies departing from a different theoretical framework when analysing the building of overseas empires, namely in the Iberian Peninsula, and more specifically in the Portuguese case. This approach has turned out to be useful to explain countless phenomena in Portuguese expansion which classic and traditional historiography seems to have missed or, very often, misunderstood.

Case study – Flows between Iberian empires

In the year 1494 the kings of Portugal and Spain (then Castile) signed the Tordesillas treaty ratifying the agreement

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139   Bonabeau, Eric, *Agent-based modeling: Methods and techniques for simulating human systems*. Paper presented at the Arthur M. Sackler Colloquium of the National Academy of Sciences, "Adaptive Agents, Intelligence, and Emergent Human Organization: Capturing Complexity through Agent-Based Modeling," held October 4–6, 2001. Available in http://www.pnas.org/content/99/suppl.3/7280.full

140   Wasserman and Faust, *Social network*, 5.

141   Ibid, 5.

negotiated after Columbus' voyage to the Americas in 1492. By this diplomatic settlement the overseas world was divided between the two crowns, and from then-on both states were very keen to protect their possessions politically and economically from one-another; nevertheless no-matter their best efforts, intense, uncontrollable, and unstoppable flows occurred between them. The analysis of these dynamics, supported by empirical evidence, will be at the focus of the presentation we intend to provide in this chapter.

Our objective is to prove that, from the early days of discovery and settlement, Portuguese agents or other foreign agents framed by the Portuguese maritime experience were active contributors to the shaping of the Spanish Empire. Christopher Columbus and Magellan are the obvious and more paradigmatic examples, but far from being the only ones. The activities of Portuguese shipbuilders, seafarers and pilots, most of them generally ignored, present a much more representative framework.

At a different level, the absence of a well-defined frontier, or better yet, the porosity of the frontier between Brazil and Spanish possessions in South America allowed permeability as well as transfers of goods and people between the two colonial spaces.

At the same time, an intense commercial activity led by Portuguese traders in order to supply slave force labour to Spanish America made possible the existence of economic dynamics on a regular basis. While the slave trade was the first extensive exchange between the Iberian overseas territories, very soon a wider range of active flows allowed and inspired in every possible way a more significant participation of Portuguese agents in the

Spanish system.

Finally, emigration flows, even when they were illegal as they frequently were during the sixteenth century, also fed Spanish colonial settlements. Post-mortem inventories of Portuguese crown subjects kept in the India Archives in Seville, as well as Inquisition proceedings against Portuguese New-Christians settled in Lima, Peru, outline this migratory current. The same reality can be verified on other documental corpora, namely the notary records from several Portuguese seaports.

These flows succeeded in overcoming institutional and political territorial boundaries, and they produced significant dynamics which worked beyond political frontiers and colonial rivalries.

They had a major impact on the worldwide framework of the so-called "First global age" (1500- 1800). We intend to provide evidence to these assertions, at different levels, through empirical data involving discoverers and pilots, merchants and settlers.

Discoverers and pilots

Even if the analytical focus is traditionally fixed on the rivalry and the competitive strategies between colonial empires and geographical expansion at a European level, we believe that none of the their expansionist projects could have succeeded without an active permeability between them, which favoured the existence of an intense circulation of individuals, as well as of information and knowledge exchanges between different political and territorial spheres.

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The inclusion of foreign seafarers and merchants in Portuguese expansion goes a long-way back into the Middle-Ages. Some of those individuals even came to be key-agents in the Portuguese discoveries. The naval accomplishments of the Genoese Luís de Cadamosto and Antonio da Noli during the Portuguese exploration of the West Coast of Africa and the discovery of Cap Verde are well known. Their presence comes from a long line of co-operation patterns which included the previous presence of Genoese seafarers commanded by Manuel Pessanha, appointed admiral of the Portuguese navy during the reign of Dinis I. (1279-1325) They were responsible for Portuguese navy reforms and for the introduction of innovative sailing techniques, as Jácome Lourenço, Bustamante and Damião Brúsio were, latter on, for the introduction and improvement of the shipbuilding industry.[142] They only announced the context in which Christopher Columbus had afterwards a leading role. Columbus can be pointed out as a major example of knowledge diffusion: he brought to Portugal both the merchant and sailing experience of the Genoese Republic and to Spain the additional knowledge he accumulated during his stay among the Portuguese, particularly during his stay in Porto Santo.[143]

In the same way, his adventure in the service of the Spanish Catholic Kings only anticipates the history of the Florentine Amerigo

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142 Amândio Barros, *Porto: a construção de um espaço marítimo nos alvores da Época Moderna*, 2 vols, (PhD diss. Faculdade de Letras do Porto, 2004), I, 764, 766-767, 795, although the origins and provenance of Bustamante are not very clear – more likely he came from Biscay, which was another area connected with Portugal very closely. A presentation of this PhD thesis is available in English: "Oporto: the building of a maritime space in the Early Modern Period, *e-Journal of Portuguese History* (e-JPH), 3, No. 1 (Summer 2005), 3-13.

143 Armando Cortesão, *Cartografia e cartógrafos portugueses dos séculos* XV e XVI, (Lisboa: Seara Nova, 1935), 225.

Vespucci under the rule of the same monarchs, or even the one of the Portuguese Ferdinand Magellan, from whose action the more obvious outcome was the first circum-navigation voyage. Magellan is one of the clearest examples of Portuguese agents acting under the service of Castile. However, abundant similar cases can be recounted, such as the one of Estevão Gomes, from Porto, Magellan's pilot on the same expedition, who later explored the North American continent for Charles V[144]. Also, João Dias de Sólis, explorer of the River Plate, nominated head pilot of Spain (Piloto Mayor de España),[145] and the famous Henrique Garcês, from Porto, one of the first – if not the first-one – who discover mercury in some of the Peruvian mines[146], could be mentioned as well.

Such are individual cases which emerge from a very significant flow of technicians, logistics and knowledge. For instance, case studies centred on Portuguese seaports prove the existence on an intense flow of smuggled ships. Crown deliberations bluntly forbade selling ships built in Portuguese shipyards to other European states, namely Spain, under motives such as the crown's needs of all the naval resources she could hold;[147] the rivalries with other states and, above all, the fiscal exemptions or the subventions invested in to promote shipbuilding. Several lawsuits and local testimonies prove, on the contrary, the existence of an active smug-

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144   Amândio Barros, *A naturalidade de Fernão de Magalhães revisitada* (Porto: Afrontamento, 2009), 38.

145   Rolando Laguarda Trías, Pilotos portugueses en el Rio de la Plata durante el siglo XVI, (Lisboa: IICT, 1988), 6-7.

146   Besides the experimentation of revolutionary methods for silver extraction using mercury, in 1558, he also discovered a few of the most important mines "in what had by then become Spanish Peru": A.J.R. Russell Wood, *The Portuguese Empire, 1415-1808*, (Baltimore: The John Hopkins University Press, 1992), 100; see also Gonzalo de Reparaz Ruiz, *Os portuguezes no vice-reinado do Perú* (Séculos XVI e XVII) (Lisboa, Instituto de Alta Cultura, 1976), 147.

147   Not to mention technical secrets the crown meant to be unveiled.

gling of ships built in Portugal to Spain and other countries. This *ship's* export can be proved both for Northern Portugal and the Algarve[148]. Such profitable commerce greatly reinforced local shipbuilding activity, improved the outputs of strategic individual investments, but can be interpreted as well as a cause of significant damages and losses to the Portuguese crown.[149] These dynamics present themselves as a major example of self-organised networks and the way they overlooked political frontiers and central power strategies.

The same could be stated for shipbuilders or a significant number of Portuguese pilots that can be found enlisted and working on the Spanish Indies maritime run. The statistical analysis of pilots' examinations to *Carrera de Indias* by the the Casa de la *Contratación de Sevilla* officials, reveals that between 1574 and 1650, e.g., before and after the Iberian Union[150] there were eight Italian, one Flemish and 41 Portuguese in a total amount of 851 pilots. That corresponds, in the Portuguese case, to 5% of the total[151].

The most striking observation is that 51% of the Portuguese pilots that were examined came from the Algarve, as shown in

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148 Amélia Polónia, *Expansão e Descobrimentos numa perspectiva local. O porto de Vila do Conde no século* XVI, (Lisboa: INCM, 2007), I, 340-342; Barros, *Porto: a construção*, 338, 680, and Joaquim Romero Magalhães, Para o estudo do Algarve económico durante o século XVI (Lisboa: Cosmos, 1970), 191.

149 Amélia Polónia, *Self organising networks in the construction of the Portuguese overseas empire*. Paper presented to the 5th International Congress of Maritime History, sponsored by the IMEHA (International Maritime Economic History Association) (Greenwich, 23-27 June 2008); Amélia Polónia and Jack Owens, "Cooperation-Based Self-Organizing Networks in Portuguese Overseas Expansion in the First Global Age." *International Journal of Maritime History* (submitted in February 2009).

150 A.G.I. - Contratación, leg. 5783.

151 The same result can be obtained by research in Spanish archives; even a plain search of records on the on-line data bases of the General Archives of Indies (Seville), or in the General Archive of Simancas for instance, will be enough to prove this assertions: by introducing the variables Portuguese pilots or Portuguese seamen between 1500 and 1600 it is possible to obtain a fair collection of mentions recording the presence of Portuguese acting under Spanish rule or, alternatively, acting on their own within colonial territories of Spanish America.

graph 1. A very different pattern can be seen in another statistical approach, this time based on the pilots' examinations held in Lisbon between 1596 and 1648 under the responsibility of the Portuguese High Cosmographer. Here, the pilots from the Algarve make up only 1.2% of the Portuguese total (6 in 353 examinations). This is greatly illustrative of the intentional decision of the Algarve pilots to seek new carrier opportunities in Spain rather than in Portugal, moving to Seville rather than to Lisbon.
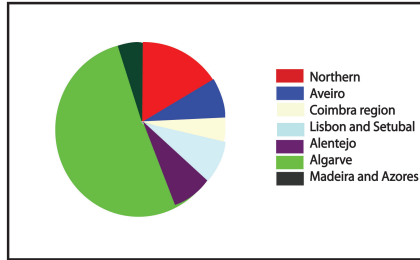
Graph 1.Portuguese pilots examinations in the "Casa de la Contratación" (Sevilla (1574-1650). **Source:** Archivo General de Indias - Contratación, leg. 5783. Apud Polónia, 2007, II, p. 46

The impact of individual decisions can be observed in a different approach of the same data. Graphs 2 and 3 show that during the period of Dutch attacks on Brazil and the Brazil route, mostly from 1630 to 1637, the Portuguese candidates gave up the exam for that route, clearly preferring the Spanish America's one.[152] In fact, the king's cosmographer was allowed to examine, in Lisbon, pilots to the *Carrera de Indias* during the Iberian Union period.[153]

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152   Amélia Polónia, "Mestres e Pilotos das Navegações Ultramarinas (1596-1648). Subsídios para o seu estudo", *Revista da Faculdade de Letras-História*, II Série, XIII (1995), 135-217, Annex A.

153   Amélia Polónia, "Mestres e pilotos", 135-217. This can also be proved by the analysis of the

This scenario also reveals the capacity of these men to choose or seek alternatives to the routes which were considered either the most promising or the less risky. We can thus observe that, at a time when the one to Brazil was by then considered dangerous, seamen proposed themselves to be examined for the routes to Spanish America, where their presence was legally recognized.
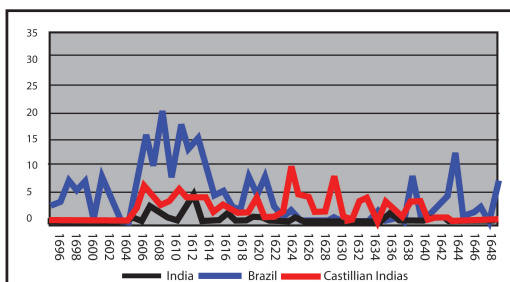
Graph 2. Pilots' exams in Lisbon. Distribution by maritime routes (1   6 1648) **Source:** ANTT – Lv. Ementas, Lv. 1-15. Apud Polónia, 1995: Annex A
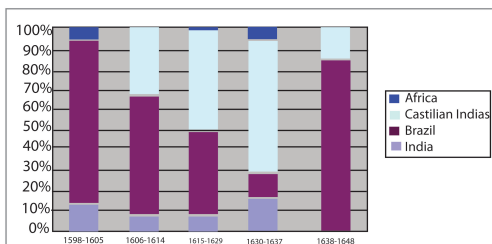
Graph 3. Chronological distribution of pilot's exams (1596-1648 **Source:** ANTT - Lv. Ementas, Lv. 1- 15. Apud Polónia, 1995, Annex A.

pilots examinations to the Spanish Indians maritime carriers held at the Casa de la Contratación de Seville, for the period between 1574 and 1650. In this sample, 5% of the candidates were Portuguese, mostly from Algarve (Amélia Polónia, "O Porto nas navegações ultramarinas quinhentistas. Embarcações e náuticos", *Revista da Faculdade de Letras-História*, 3ª Série, 1 (2000), 29-52.

These conclusions are confirmed by the results obtained in a case study centred on Vila do Conde, a small seaport located about 30 km north of Porto, on the north-western coast of Portugal, during the period from 1560-1620, as we can see in Graph 4 and Map 1.
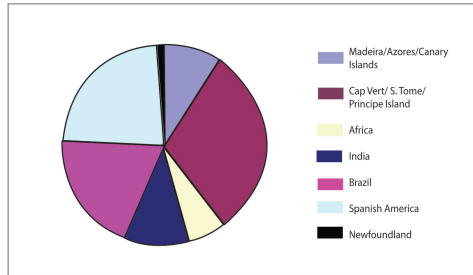
Graph 4. Vila do Conde's navigation routes (1560-1620)
Source: Polónia, 2007: 33
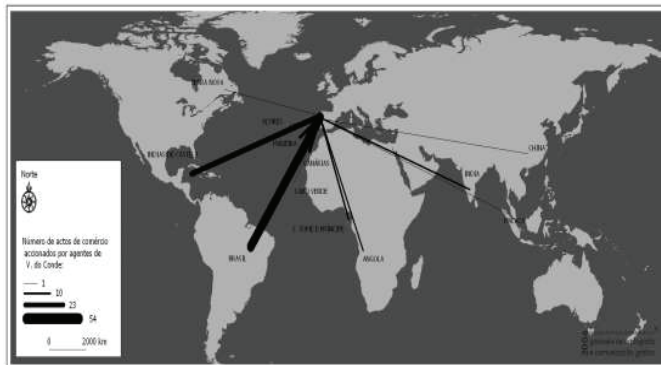
Map 1. Navigation destinations from Vila do Conde (1560-1620)
Source: Polónia, 2007: II, 38

These representations show that Brazil and Spanish America were the main overseas destinations for the ships and seamen from Vila do Conde. A similar trend can be stated for Porto, even if with a quite minor incidence on Spanish America[154]. The apparently lower figures for Porto which could be interpreted as lesser participation, are in fact a consequence of the lack of documental evidence from the first decades of the seventeenth century, a period for which a growing participation of Portuguese agents on these traffic circuits is well documented elsewhere, both in the Portuguese archives and in the General Archive of Indies in Seville.

Map 2. Navigation destinations from Porto. 16th. Century ***Source:*** Barros, 2004: 709

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154   In terms of navigation routes from the city, ship charts to that destiny were generally not reported, which additionally proves that the maritime contacts were performed at a private and individual level; however, if we take a close look at the emigration trends and also at the number of ships from Porto arriving in Spanish America from Brazil or the coast of Africa, these figures increase and reveal the same tendency. From those information's (especially from the news about emigrants), there can be no doubt about Porto's commercial trade networks in the Spanish overseas empire whose merchandise was commonly traded in the city. See Barros, *Porto: a construção*, I, 108, 398, 468.

The study of the data available makes clear that these options did not result from abstract decisions, based, for instance, on preferences for a given maritime route. On the contrary, seafarers and ship-owners had a very concrete and well defined goal: they were looking for employment and they were almost entirely at the service of merchants and trade circuits. The statistic and cartographic representations reflect precisely those trade circuits.

As can be proved in the Vila do Conde and Porto case studies, such tendencies and business options are directly connected and framed by the African slave trade to Spanish America.

Slave trade

Legal frameworks are essential to comprehensively understand the slave trade circuits which crossed Portuguese and Spanish empires, since the traffic depended on the concession of licenses which stipulated the number and the ports of arrival of the slaves going to the West Indies. However, the presence of individual agents, private initiatives and self-organised networks also took part in this domain, both inside and outside the legal framework, through business arrangements and smuggling[155].

At first, the Spanish crown intended to adopt a rigid monopoly over the navigation and trade circuits to America, by

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155   On this subject, besides the earlier works of Maria Manuel Torrão, *Tráfico de escravos entre a Costa da Guiné e a América Espanhola. Articulação dos Impérios Ultramarinos Ibéricos num espaço Atlântico* (1466-1595), 2 vols. (PhD diss. Universidade de Lisboa), and Maria da Graça Ventura, *Negreiros Portugueses na Rota das Índias de Castela* (1541-1556), (Lisboa: Colibri, 1999), recent contributions for the period 1580-1674 were made by Filipa Ribeiro da Silva, *The Dutch and the Portuguese in West Africa. Empire building and Atlantic system* (1580-1674), (PhD diss., University of Leiden, 2009).

settle-on exclusive departures from Seville.[156] That should include the slave trade as well, in which the Portuguese were the main agents and the Portugal's African possessions the main supplier markets. However, such intention hardly succeeded in general, and certainly not for as slave trade was concerned. As García-Baquero stresses, the monopolistic structure of the colonial economy was one thing; fitting the slave trade into that strict structural organisation was quite another.[157]

This inadequacy was responsible for notorious evolutions on the regime of that specific traffic. In the first decades of the 16th century the legal slave trade determined that slaves from Africa (at first mostly from Cap Verde) should be brought directly to Seville and from here they would be re-distributed to Spanish America. The complexity of the system and the disadvantages (and awful discomfort) of taking slaves from Africa to Lisbon, from there to Seville and finally acros the Atlantic, encouraged direct trade routes from Cap Verde to the Antilles. The growing number of slaves transferred –very often illicitly, through convenient contracts with Spanish partners– between those worlds was an additional element which pushed in the same direction.

From 1513 onwards crown licenses to introduce slaves to America were mandatory and implied previous taxation. Emperor Charles V (Charles I of Spain) changed the system by granting an eight-year monopolistic contract of 4000 slaves to be sent to West Indies by Lorenz de Gouvenet, a Flemish trader. When Gouvenet in turn sold several sub-licenses to third parties, the system became

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156   García-Baquero González, *La carrera de Indias: suma de la contratación y océano de negocios*, (Sevilla, Algaida Editores, 1992)
157   García-Baquero González, *La carrera,* 234.

open to external trade agents, initially mostly Genoese. This regime helped to set up trade, and attracted financial and administrative networks which were able to create lobbies and very soon took over the control of the system. Portuguese agents, who run the African markets and the Atlantic navigation, became a part of those lobbies. The new system also opened the first direct connections between Africa and Spanish America, although the indirect routes via Seville (or, at least, the Canary Islands) remained in use.[158]

At the same time, the Portuguese crown, which intended to improve settlements in Cape Verde and in San Tome, granted privileges to spontaneous settlers able to trade with local merchants on the African Coast. These privileges motivated the establishment of local networks which were bound to produce significant damage to the Portuguese crown's fiscal rights. Aware of heavy loss in their revenues, the Portuguese king removed those privileges and subsequently created a Crown factory in Santiago (Cap Verde). However, trade networks were already firmly established and were able to maintain their enterprises with significant gains.[159] From that moment-on, self-organized and powerful networks could also take part in and profit from the slave trade.

Later trade circuits, departing from the Gulf of Guinea, Congo and Angola, were directed to Cartagena, in Spanish Indies. They were added to, and very soon largely overtake, those already existent, departing from Cap Verde and arriving in the Antilles.

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158   A summarized approach to this scenario can be checked at Torrão, *Tráfico de escravos,* 199-223.
159   Marília Lopes, "A exploração económica da Guiné e Cabo Verde nos séculos XV e XVI" in Portugal no Mundo, dir. Luís de Albuquerque (Lisboa: Alfa, 1989), 1, 250-263; Carlos Riley, "Ilhas Atlânticas e Costa Africana" in Francisco Bettencourt and Kirti Chauduri, dir. *História da Expansão Portuguesa*, (Lisboa: Circulo de Leitores, 1998), 1, 137-162.

Either way, and most important, participation in the traffic was only possible through means of co-operation between Portuguese and Spanish colonial and political agents: while the king of Spain provided licenses to trade slaves in West Indies, the Portuguese king controlled the African markets. Business networks and corporations of Portuguese, Spanish, Flemish and Genoese brokers took place, and they cumulated resources in order to meet the financial, administrative, legal, and transportation means that were required by the traffic.[160] Even the Portuguese king John III joined as a partner in some of these contracts, and it is important to stress that the kings' associates in these business ventures were either Portuguese or Castilian merchants already involved in the slave trade.[161]

Significant changes were introduced by the Union of the Portuguese and the Spanish Crowns (1580-1640). By then, the king's court stayed in Madrid, where the asientos (the Spanish licenses to trade slaves) were granted and the contracts were negotiated and signed. This led the Portuguese to Madrid; gave them easy access to the Spanish asientos and also reinforced trade and financial networks between empires[162], as can be seen by the role of the firm of Rodrigues de Évora in the second half of the century.[163]

Furthermore, in 1586, Philip II of Spain (Philip I of Portugal) decided to reform the licences' system.[164] His decision derived from

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160   Torrão, *Tráfico de escravos,* I, 205-232.

161   Ibid, 224

162   Silva, *The Dutch*, 214-215.

163   J. Gentil da Silva, *Stratégie des affaires à Lisbonne entre 1595 et 1607. Lettres marchands des Rodrigues d'Évora et Veiga*, (Paris: S.E.V.P.E.N.,1957).

164   Concerning the evolution of the supply system of slaves to the Spanish Americas see, for instance, Leslie B. Rout, *The African Experience in Spanish America* (Cambridge: Cambridge University Press, 1976), pp. 37-61: Henriqueta Vila Vilar, "Los asientos portugueses y el contrabando de negros", *"Anuario de Estudios Americanos"*, 30 (1973), 557-599.

the increasing need of manpower to feed the sugar plantation in the Antilles, namely in Cuba, as well as the huge requirements from the growing exploitation of silver and gold mines in the Caribbean, New Spain, Central America and most of all Potosi.[165] Consequently, between 1586 and 1640, the Habsburg Kings negotiated contracts for the regular supply of African slaves to the Spanish American colonies – the so-called asientos de negros.[166]

In this new context, it was no longer illegal to send Portuguese ships, with Portuguese crews, from the West Coast of Africa to the Spanish Americas[167], even if they weren't legally allowed to disembark.[168] The most striking proof that these restrictions were often disregarded remains the repeated correspondence between officials and the illegal emigration of Portuguese in Indies, as we will see below.

Evidence on slave trade from Portuguese seaports, which can be confirmed from Porto and Vila do Conde case studies[169], helps us to understand how these commercial ventures reinforced an Atlantic system, connecting Europe, Africa and America, and built colonial economic networks on a global basis, which necessarily crossed empire frontiers.

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165   Frederik Browser, "Los Africanos en la sociedad de la America Española Colonial" in Leslie Bethel, coord. *America Latina Colonial* (Barcelona: Crítica, 2003), 79-98; Peter Bakewell, *Minería y sociedad en el México Colonial. Zacatecas* (1546-1700), (México: Fondo de Cultura Económica, 1986); Peter Bakewell, "Estado y menería en la Hispanoamerica colonial", in I*ndustria y estado en la vida de México*, Patricia Arias, coord. (Zamora: El Colegio de Michoacán, 1990), 43-55 "La minería en la Hispanoamérica colonial" in Nicolas Sánchez-Albornoz et. all - *América Latina na Época Colonial*, (Barcelona: Critica, 1990), 2, 79-98.

166   Cf. Rout, *The African experience,* 23-59; Vila Vilar, *Los asientos,* 23-59.

167   Silva, *The Dutch,* 215

168   Fernando Serrano Mangas, *La encrucijada portuguesa. Esplendor y quiebra de la unión ibérica en las Indias de Castilla* (1600-1668) (Badajoz: Diputación Provincial, 1994), 18

169   Barros, *Porto: a construção,* I, 401; Polónia, *Expansão e descobrimentos,* II, 171-188.

Map 3. Slave trade circuits led by Porto merchants (16th. Century)
Source: Barros, 2004: 678

The growing participation of Portuguese seaports in maritime routes to the West Indies is proved both by the already mentioned examination of ship's pilots and the data resulting from the case studies we've just been through. The massive introduction of Portuguese crews and merchants on these circuits created new trade opportunities, even if illegal, and resulted in a significant presence of Portuguese settlers in Spanish American colonial dominions.

Some empirical evidence of these matters can be visualised by the following graph and map, based, again, on the Vila do Conde case study for the period 1560-1620.
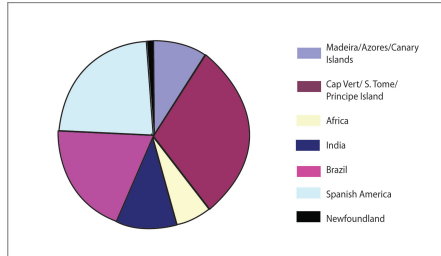
Graph 5. Vila do Conde's overseas trade circuits (1560-1620)
Source: Polonia 2007: II, 177.
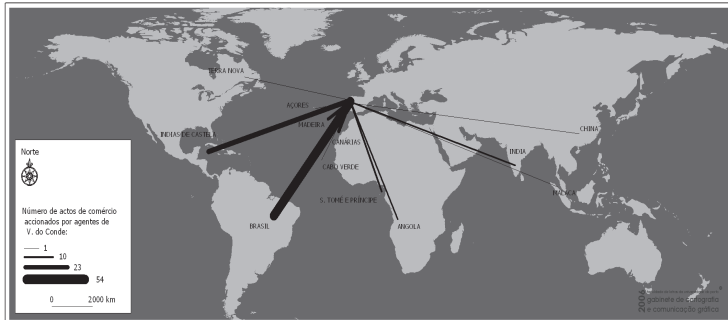
Map 4. Vila do Conde's overseas trade circuits (1560-1620)
Source: Polonia, 2007: II, 176

The 1640's Portuguese Restoration War (1640-1668) introduced a new context and a new framework with consequences for this flow. In fact, the commercial routes between Portugal and the Spanish West Indies were suspended. Moreover, the embargoes imposed by the Portuguese and the Spanish kings on each other's vessels during the conflict, and the Dutch takeover of Angola

and São Tomé in 1641, should have rendered impossible to carry on with these commercial and navigation routes. Nevertheless a question arises – should we take that for granted? We are not able to give a definitive answer to this question, since the research data available report mostly to the period previous to 1640. However, based on other examples of similar situations in the Portuguese colonial dynamics, including the studies on smuggling strategies and trends, we would argue that the trade networks somehow managed to keep going on.

Firstly, the most important Portuguese merchant bankers settled in Madrid remained there[170], in person or represented, and were able to maintain very dynamic webs of business, capital and trade. Secondly, an immediate replacement of the Portuguese as slave suppliers would have been impracticable while the need for African slaves remained a forceful element in the Spanish Americas. Even if the Dutch took San Tome and Angola, in 1641, they held them only briefly and lost them to the previous settlers – the Portuguese. As for Elmina, kept by the Dutch from 1637 onwards, which is often considered a supplier slave market, it never had, in fact, a significant impact on that trade during the Portuguese domination.[171] In the third place, the undefined and uncontrolled frontiers between Brazilian and Castilian Indies territories generated an unstoppable flow of trade, capital and business which was not affected nor reversed by the short period of a distant war in Europe (1640-1668). In fact, as stated by Ribeiro

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170   Carmen Sanz Ayán, "El crédito de la corona y los hombres de negocios en los últimos años del reinado de Felipe IV", in *Cuadernos de Historia Moderna*, 9 (1988), 63-94

171   J. Bato' Ballong-Wen-Mewuda, *São Jorge da Mina. 1482-1637. La vie d'un comptoir portugais en Afrique Occidentale*. 1482-1637, (Lisboa – Paris: Fundação Calouste Gulbenkian, 1993.

da Silva, until the mid-1650s, the Southern Brazilian captaincies worked as a re-distribution centre to supply slaves to the Plata region, while until 1654, Dutch Brazil functioned as a re-distribution centre for the Spanish Central American mainland and the West Indies.[172]

More recently, a research by Gleydi Sullón about the Portuguese in Piura, Peru found that although with restrictions (for example confiscation of weapons and closer surveillance by the local Inquisition), the presence of settlers and traders coming from other parts of Peru and even from Europe remained very noticeable after 1640. Actually, most of them remained in business, benefiting from the strategic position of Piura (bisagra comercial) on the trade route between Quito and Lima.[173]

Finally, even if with additional restrictions and blockades, the very active navigation and trade circuits which numerous small-to-medium entrepreneurs located in several Portuguese seaports guaranteed in a self-organized and informal way did not disappear immediately. These networks tended to subsist despite the changes of the political context, even if we cannot deny that naval war could affect them in a significant way.

Those are the very same agents who usually kept in place illegal networks and mechanisms, including smuggling, a phenomenon which could only be carried out with co-operation between frontiersmen and between subjects of different and frequently opposing kingdoms. What we aim to state is that they

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172   Silva, *The Dutch,* 218.
173   Gleydi Sullón Barreto, *Portugueses en el Perú y los padrones de registro de 1642. Piura y Trujillo,* (Unpublished paper), (Piura, 2009), 6, 10. Between several merchants, Sullón refers the arrival in Piura, in 1645, of Gaspar da Silva, from Porto, Portugal, a trader of cloth doing business. "Resident in Guaura", he made his testament and last will in Piura.

were, eventually, stable networks that keep functioning while the gains remain bigger than the losses, despite the official policies which imposed a breakdown for long or short term cooperative networks.

The colonial powers and authorities seemed to be and probably were aware of that, so it explains the massive harassment of the Portuguese New Christian merchants in the Spanish American colonies, by the Spanish crown, through the Inquisition, forcing them to leave and to break up a wide web of familial and business networks, namely in the Plata region, where they held a dominant position in the silver trade. These webs also comprised the circuits that connected some of the main Spanish American ports (Cartagena and Vera Cruz) to the mining centres in the hinterland, and to the ports on the Pacific Coast. According to Daviken Studnicki- Gizbert, all these circuits were affected by that persecution.[174]

Emigration flows

There are not many studies based on serial data and official indicators about Portuguese emigration flows for the period before the eighteenth and even the nineteenth centuries. The lack of sources constitutes an obstacle impossible to overcome. As regards Portuguese emigration to the West Indies, this deficit extends to the official records of the Casa de la Contratación, which managed the concession of emigration licenses.

The restrictive emigration policy pursued by the Castilian crown since the very beginnings of the American colonial settlement

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174   Daviken Studnicki-Gizbert, *A nation upon the ocean sea. Portugal's Atlantic diaspora and the crisis of the Spanish empire*. (Oxford: Oxford University Press, 2007), 15-174.

is well known. The legal pattern was based on the control over the religious orthodoxy, so that all non-Catholics, including Muslims, Jews, Conversos/New Christians, and later-on all of those convicted by the Inquisition, were excluded[175]. Initially, these measures also imposed restrictions on the introduction of slave African labour force, based on the religious practices need for control.[176] From 1505 onward the immigration of foreign agents was also forbidden, even if between 1526 and 1538 it was allowed for Italian and German Hapsburg subjects. Since it was illegal, the entry of any foreign immigrant, including Portuguese subjects, was not registered; and that explains the absence of data – mainly statistic– about Portuguese emigration to Spanish Indies.[177]

This legal framework represented an impediment to emigration. But sometimes this obstacle was diminished since Spanish authorities only imposed certain requirements concerning the permission for Portuguese immigrants by allowing married men and women to settle in the Americas. Such legislation – vast and frequently altered – shows great complexity and asks

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175   *História de Iberoamerica. Tomo II: Historia Moderna*, Manuel Lucena Salmoral, coord. (Madrid: Cátedra, 1992); Richard Middleton, *Colonial America. A History*: 1585-1776. (Oxford: Blackwell, 1997); Leslie Bethel, *América Latina Colonial,* (S. Paulo: Edusp, 1998).

176   Frederic Bowster, *The African slave in Colonial Peru.* 1524-1650 (Stanford: Stanford University Press, 1972), 27-28; Rozendo Sampaio Garcia, "Contribuição ao Estudo do aprovisionamento de escravos negros na América Espanhola (1580-1640)", in *Anais Paulista*, XVI (1962), 13-14, and Esteban Mira Ceballos, "Las licencias de esclavos negros a Hispano America" (1554-1555)", in *Revista de Indias*, LIV, 201 (1994), 273-297.

177   The study of this phenomenon can, although, be achieved through local archives in Portugal, from municipalities to notary and parish records. For a brief discussion of this subject, see Helena Osswald and Amélia Polónia, "No reverso do Tratado das Tordesilhas: Portugueses nas Índias de Castela durante o período de união dinástica", in *Vértice*, second series, No. 63 (November-December 1994), pp. 45-54. See also Maria da Graça A. Mateus Ventura, 1996 – "Portugueses nas Índias de Castela. Percursos e percepções," in *Viagens e viajantes no Atlântico Quinhentista* (Lisboa, Colibri, 1996), 101-132, and Maria da Graça A. Mateus Ventura, *Portugueses no descobrimento e conquista da hispanoamérica: viagens, expedições e trato* (PhD diss. Lisboa: Universidade de Lisboa, 1997).

for a more comprehensive study. In the present case we were able to acknowledge seventeen royal provisions (or decrees) granted between 1510 and 1540 in which immigration endorsed by the king at the request of Spanish captains involved in overseas enterprises. The official Spanish political thought about immigration, balanced between prohibition (which was in any case less evident) and allowance, which depended on major colonization needs. The standpoint was general restriction, of course, but in view of the lack of people in the colonies (or even in the ships) the authorities had to compromise, and even favour the Portuguese immigration.[178]

We must be aware that these migratory streams documented by the empirical data under analysis occurred even before the great Northern Portuguese ports movement towards Brazil, at the first decades of the sixteenth-century[179]. And yet, some empirical evidence of the same tendency can be sustained by the following graph and map, based, once more, on the Vila do Conde case study, now applied to another chronological period and a different contextual framework.

The available figures from Vila do Conde between 1560 and 1640 result in the following charts:

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178   For instance, in the 27th April, 1528 Charles the Fifth allowed García de Lerma to take with him to Santa Marta, Venezuela, 50 married Portuguese settlers; however as it was impossible for Cabrera to find them, in the 30th June, another royal provision changed the number of married men to an half and allowed other 25 unmarried Portuguese to embark with him. AGI – Audiencia de Panamá, 234, liv. 3, fl. 172-172v and AGI – Audiencia de Panamá, 234, liv. 3, fl. 174-175v.
180   The most part of them (fifteen) occurred between 1520 and 1536.
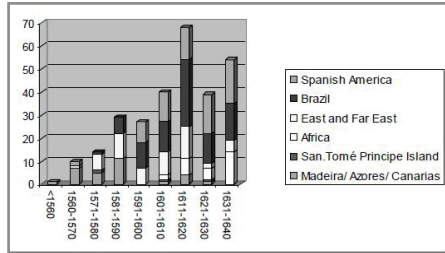
Graph 6. Vila do Conde's settlers overseas. Diachronic and spatial distribution (1560-1640) *Source:* Polónia, 2007: II, 240.
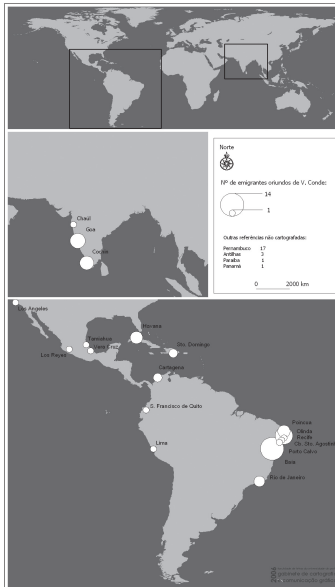
Map 5. Vila do Conde's emigration flows overseas (1560-1640 *Source:* Polónia, 2007: II, 242.

From the diachronic distribution of the data it is quite evident that the Spanish Indies were included among the destinies of emigration of Vila do Conde's people. This tendency seems to be connected with the approval of licenses for direct navigation departing from Africa resulting from slave trade ventures, precisely in the 1590´s, just ten years after the Iberian Union.

Additional research in the General Archive of Indies, in Seville, confirms this tendency, through the *autos de bens de defuntos* (property inventories from Europeans who died in colonial territories). According to these accounts, the illegal status of the deceased frequently determined high penalties in their legacies. This applies to Francisco Barroso, a pilot and merchant from Vila do Conde who died in Peru after he concluded a slave trade contract from which resulted the considerable sum of 2.250.000 Portuguese *reais*[180]. According to the lawsuit that followed his decease, about half of the amount was retained by Spanish officers arguing that he stayed in Peru illegally. However, as it was recognized by local testimonies, he maintained a long-term residence in Peru, as well as another one in Lisbon, where his family lived at that time.

He was just only one among the several Vila do Conde inhabitants that we could identify in a plain research in the Spanish Archives. Besides this multi-active sea pilot, it is possible to find another one who died in Cordoba, in Peru[181] ; a few seafarers[182] , some of them becoming mechanical crafters[183] ; shipbuilders[184] , farmers and cattle producers[185] , among others whose professional

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180   A.G.I. - Contratación, 384, n. 3, r. 10.
181   A.D.P. (Porto District Archive) – Fundo Notarial. V. Conde, 1º cart., 1ª sr., lv. 30, fl. 19-21.
182   A.G.I., Contratación, 5576, n. 2.; A.G.I., Contratación, 273, n. 13.
183   Idem, 941 B., n. 12.
184   A.D.P. Fundo Notarial. V. Conde, 1º cart.,1ª sr., lv. 21, fl. 10v.-13.
185   Idem, 237, n. 3, r. 21; Idem, 526, n. 1, r. 1.

occupation was impossible to be identified.[186] Similar patterns are spotted in Porto where the documental sources reveal the departure of men specialized in crafts such as ship carpenters, rope-makers, caulkers, and coopers, which were in great demand overseas.[187]

The overall territorial distribution of these people is quite impressive (see map 5 concerning Vila do Conde's emigration): they spread over an area which includes the Antilles, Mexico, including Los Angeles; Peru mostly to Lima; Cartagene, in nowadays Colombia; Trujillo on Honduras, Panama and Quito, in Equator. The same trend and directions were also followed by the Porto overseas emigrants, whose presence is documented in the Antilles (Puerto Rico, Cuba, Santo Domingo), Mexico, Peru, Honduras, Columbia, Chile, and several other Spanish American regions.[188]

This web demonstrates a pattern of distribution which presumes a large dominium and influence spread over a significant territory, confluent with the hypothesis that one of the main ways to gain entry into the West Indies was by navigation. The enrolment of Portuguese emigrants and sailors in the Spanish West Indies carrera, and their involvement in slave trade circuits benefited from the accessibility provided by sea routes, and uncontrolled traffic, as other documental corpus repeatedly testifies[189]. However, further and abundant case studies need to be scrutinised in order to analyse this subject in depth.

With the exception of pilots and slave traders, the individ-

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186   A.G.I., Contratación, 513 B., n. 4, r. 6.
187   Amândio Barros, *Porto: a construção*, 242.
188   Ibid., 399, 401, 426, 600, 680, etc.
189   Another way to reach the Spanish Indies was to sail from Brazil as it is mentioned in the notary records of Porto in legal documents concerning the confiscation of sugar by the Spanish authorities in Porto Rico. See Amândio Barros, *Porto: a construção*, 818.

uals that were identified on a casual basis had limited wealth or
fortunes, according to the death registers and inventories. This is
not however, the case of the large Sephardic communities, whether
observant Christians or Jews, many of whom from Portuguese an-
cestry, which stand out as being quite wealthy. This trend is well
proved by the persecutions led to those communities by the Lima
Inquisition, despite the regulations of the Castilian Crown which, as
we just saw, forbade their emigration to the American domains.[190]
Their presence provides another example of these transnational
and trans-religious forms of cooperation, settled by informal and
self-organised networks, frequently in an illegal way.

This pattern is well documented, however not limited to
the period of the Iberian Union. It was certainly with emigration
and business on their minds that the Portuguese delegates in the
parliament that recognized Philip II as king of Portugal strongly
demanded him to recognize and legalize their fellow countrymen in
the West Indies.[191] As we saw previously, the Spanish immigration
laws since the beginning of the sixteenth century were often
permissive regarding the acceptance of Portuguese married
couples. Other examples can be quoted – a document from 1568 in
the General Archive of Indies mentions Portuguese settlements on
the Florida coast, where they were building fortresses[192]; another
dated 1573 granted licenses to 100 Portuguese farmers to go to
Florida with their families, despite the legal restrictions.[193] Even

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190   On this matter, see: Gonzalo de Reparaz Ruiz, *Os Portuguezes no vice-reinado*; Fernando Serrano Mangas, *La encrucijada portuguesa*, 19-23.
191   Amândio Barros, *História do Porto. (O tempo dos Filipes. A cidade e a construção do mundo global),* vol. 6. (Matosinhos: QudiNovi, 2010), 43-46.
192   AGI, Indiferente, 425, lv. 24, fl. 380-381.
193   AGI, Indiferente, 426, Lv. 25, fl. 242v.-243.

before, in 1564, a Portuguese died intestate in the Lima District, and another-one was killed by the Indians in Guane Province.[194] These are casual references which emerge from a much more consistent flow which, even in the early days of the Spanish settlements, resulted in documentary evidence for the presence of numerous Portuguese, as pointed out by Serrano Mangas.[195] For a later period (1642), the same author considers that the number of Portuguese families was underestimated by about 1600 (cc. 4000 inhabitants at least, considering the demographic patterns of Ancien Regime) in the Province of New Spain only.[196]

Conclusion

To sum up, the empirical data analysed in this chapter, even if taken only as samples, is very enlightening either for the indisputable presence of Portuguese in the Spanish Indies, as they are a truthful evidence of informal and self-organized Portuguese international networks acting in that part of the Early Modern colonial world. Through the examples we just came to describe, we come across to a sort of global interaction. This kind of widespread interaction was not only limited to the Americas – it was also extended to the financial and commercial contacts spread all over Europe such as the ones throughout the Iberian Peninsula, namely through the Medina del Campo fairs, Madrid, Lisbon and Seville, or the others which were located in the Northwestern European cities such as Antwerp (and later-on, Amsterdam), and also in Paris,

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194   AGI, Contratación, 202 B.
195   Fernando Serrano Mangas, *La encrucijada portuguesa* , 1994: 17
196   Ibid, 20.

Besançon, and Hamburg, from where capitals flowed. Those networks involved frequently business that connected, again, Portuguese and Spanish overseas trade and their interests in international financial circuits.

Individual agents managed to establish valuable contacts with partners abroad and with foreign traders, and became associated in overseas commercial ventures, which went far beyond national boundaries and restrictions. When we check closely to the way those agents acted, they proved to be able to disregard literally the institutional, political and territorial boundaries, and introduced significant dynamics to merchant, demographic and social activities. They deliberately ignored colonial rivalries, and through a unyielding activity they were in fact active participants and builders of the so-called Atlantic empires. From the modest emigrant, the craftsman, the settler, and the seaman acting as colonizer, the shipbuilder, the pilot, to the trader or the banker who financed overseas enterprises, all of them produced a major impact on the world economy and contributed extensively to the "First Global age".[197]

Modelling and Implementation of a spatio-temporal historic GIS

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Introduction

The application of GIS in Historical research is a relatively new field since GIS technology has been mainly applied to natural sciences. However, there exist several examples of the utilization of GIS, with an increasing frequency, where the use of this technology has been appreciated for the analysis of historical data of a very diverse nature. A field where the use of GIS is becoming increasingly common is the demographic studies,[198] as well as in archaeological research[199]. Owing to their ability to analyze spatial components, GIS have been proven very useful in the study of mapping histo

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[198]   George William Skinner, Mark Henderson and Yuan Jianhua, "China's Fertility Transition through Regional Space: Using GIS and Census Data for a Spatial Analysis of Historical Demography," *Social Science History* 24 (2000): 613-652.
[199]   Kathleen M. Allen, Stanton W. Green, and Ezra B.W. Zubrow, eds., *Interpreting Space: GIS and Archaeology* (London: Taylor and Francis, 1990), 398.

rical boundaries[200], as well as in migration analysis[201] or urban form studies. Examples of the use of GIS are also found in regional economic analysis.[202]

Other fields where GIS are widely used are the development of education-oriented electronic atlases, such as de ECAI Project - Electronic Cultural Atlas Initiative. It is worth mentioning other initiatives that approach new topics such as the potential uses of GIS on the history of print culture.[203] Those are only a few examples of the wide range of applications of GIS in historical research. Building a spatial database implies an abstraction process in order to go from real world complexity to a simplified representation that is accessible to the computer's language; in this case, the reality historians try to reconstruct based on data gathered from diverse sources is related with Self-Organizing Networks of the First Global Age (1400-1800).

The decision to create a Geographic Information System (GIS) to handle such great volume of heterogeneous information from the DynCoopNet project (Dynamic Complexity of Cooperation-

200   Onno Boonstra, "Mapping the Netherlands, 1830-1994: The use of NLKAART," in *Coordinates for Historical Maps*, ed. Michael Goerke (Göttingen, Germany: Max-Planck Institute, 1994). 156-61. Loren J. Siebert, "Using GIS to Document, Visualize, and Interpret Tokyo's Spatial History," *Social Science History* 24 (2000): 537-574; Ian Gregory and Humphrey R. Southall, "Putting the past in its place: The Great Britain Historical GIS," in *Innovations in GIS* 5, ed. Steve Carver (London: Taylor & Francis, 1998), 210-221.
201   Ian Gregory, "Longitudinal Analysis of Age- and Gender- Specific Migration Patterns in England and Wales: A GIS-Based Approach," *Social Science History* 24 (2000): 471-503. Steve Hochstadt, "Outdated geographical models of migration" (paper presented at the *Social Science History* Association conference, Fort Worth, TX, November 13, 1999); Moch, L. P., "Overcoming inmobility: Source, method, and ideology in the study of French migration" (paper presented at the *Social Science History* Association conference, Fort Worth, TX, November 13, 1999)
202   Richard G. Healey and Trem R. Stamp, "Historical GIS as a Foundation for the Analysis of Regional Economic Growth Theoretical, Methodological, and Practical Issues," *Social Science History* 24 (2000): 575-612.
203   Bertrum M. MacDonald, and Fiona, A. Black, "Using GIS for spatial and temporal analysis in print culture studies: some opportunities and challengues," *Social Science History* 24 (2000): 505-536.

Based, Self-Organizing Networks in the Global First Age) was based on the data's spatio-temporal component. That is to say, most of these data can be georeferenced to a specific date and location, which will facilitate to carry out complex analyses with the GIS which will help to understand the organization of those networks, their operations and impacts in a time period covering four centuries of history, as well as to represent the results graphically through thematic cartography by making use of the GIS geovisualization potentials. Understanding the functioning and the mechanisms that led to the evolution of self-organizing, complex, social networks in the First Global Age necessarily implies an understanding of the changes that occurred in these networks throughout space as well as throughout time. Hence the need to approach these questions from a spatio-temporal conceptual framework that can be translated into a GIS that is capable of handling both dimensions. In this sense GIS, which have been mostly used so far in the field of natural sciences, are beginning to greatly appeal to researchers in the field of human and social sciences owing to their potential for handling great volumes of information as well as their visualization and analysis.[204]

The creation of a GIS implies a series of phases, such as conceptualization, design, or implementation. The *conceptualization* phase is one of the most important since in it we define, among others, the objects or entities that will make up the system, their attributes and their relationships; they are also hierarchically structured, codified when necessary and assigned a way of representation. In GIS, a data model is the abstraction of the

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204   J. B. "Jack" Owens, "Toward a geographically-integrated, connected world history: employing geographic information systems (GIS)," History Compass 5 (2007): 2014-2040.

real world phenomena according to a formalized, conceptual scheme, which is usually implemented using the geographical primitives of points, lines and polygons or discretized continuous fields.[205] Therefore, a data model should define data type, relationships, operations and rules to maintain database integrity.[206] Besides, the way data are accessed also has to be defined. The fundamental pillar on which to build a historical GIS such as that in the present project is to design a solid, consistent conceptual data model that integrates all data and is scalable and with great potential, capable of responding to any questions and scientific objectives raised by the end user. Therefore, the ability of the GIS to exploit the information stored will depend on the design of the data model, hence the importance of devoting to this phase as much time as needed and of working in a team with historians and specialist technicians that are proficient in this type of technology.

The following phase is the *design* one, where the analytic operations to be carried out in the system are defined and a physical data model is created which materializes into a specific database and a data structure for the spatial data. In the case of DynCoopNet, since the issue is that networks and their dynamics have to be studied throughout time, during the planning stage for the development of the GIS a vectorial model has been chosen since it is more efficient than the raster model. The vectorial model is based on spatial objects which are represented as points (e.g.: ports, cities), lines (e.g.: routes of ships) or polygons (e.g.: mercantile areas, countries), on their properties and the topological relation-

205   Peter A. Burrough and Rachael A. McDonnel, *Principles of Geographical Information Systems* (New York: Oxford University Press, 1998).
206   S. Nadi and and M. R. Delavar, "Spatio-temporal modeling of dynamic phenomena in GIS", in *ScanGIS 2003 Proceeding* (2003), 215-225.

ships established among them, whereas the raster model places the emphasis on localizations themselves, dividing the space into equal-size pixels to which diverse alphanumeric information is attached.[207] The vectorial model is more adequate for historical analyses since it handles events better than the raster model and thus represents in a better way human activity and the causes and consequences of the changes in a specific process, etc. The vectorial model also allows for a more detailed granularity when approaching reality, such as, for instance, in the representation of the routes of the ships' trips in which a complete analysis can be carried out taking account of the ports of departure and arrival, or make approaches to each stage of the journey down to the highest level of detail by modifying the scale of analysis, stopping at the ports of scale where events, deals or relations of cooperation took place.[208]

The last phase is the *implementation*, the system created, which is a physical translation of the conceptual model, it is perfectly integrated with ArcSDE®, a tool that stands half way between a data model and a geo-visualization and space analysis tool used in this project, ArcGIS®. The technical team has chosen PostgreSQL to store data, a sophisticated open source Object-Relational Database Management System (DBMS). This system allows, once the model is implemented in a database, an immediate connection by the user and the possibility to carry out studies and analysis on the data sets. Certain studies and analyses will be available directly from the

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207   Donna J. Peuquet, "It´s about time: a conceptual framework for the representation of temporal dynamics in Geographic Information Systems," *Annals of the Association of American Geographers* 84 (1994): 441-461.
208   Mónica Wachowicz, "Modelos Conceptuales de Base de Datos Espacio-Temporales," (paper presented at I Seminario de Historia y SIG, Centro de Ciencias Humanas y Sociales, CSIC, Madrid, July 3, 2009).

system whereas others will require certain preparation of the data sets based on auxiliary tables and external tools. The materialization of the conceptual model in a spatial database and the potentiality of the GIS will allow, among other things, to model the cooperation relationships among agents, the commercial flows, the dynamics of the commercial networks and their degrees of cohesion.

A review of the spatio-temporal models for GIS applications

One of the early contributions that approaches the question of integrated time in GIS is that by Gail Langran. This author contributes examples of applications where the temporal component becomes very important.[209] Spatiotemporal data is spatial data that changes with time, so spatiotemporal data is a series of spatial data changes.[210] GIS have at their disposal a great deal of tools for analyzing great volumes of information. Any data that is to be integrated into a GIS is made up of three inter-related components - attributes, space and time.[211] The attributes or properties of objects answer questions like 'What?', the space reply to 'Where?' and the time to 'When?' ones[212] (Peuquet, 1994). However, most commercial software does not implement temporal

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209   Gail Langran, *Time in Geographic Information Systems* (London, Washington, DC: Taylor & Francis, 1992).

210   Mohd Shafry Mohd Rahim, Abdul Rashid Mohamed Shariff, Shattri Mansor, and Ahmad Rodzi Mahmud, "A review on spatiotemporal data model for managing data movement in geographical information systems (GIS)," *Jurnal Teknologi Makluma,* 17 (2005): 91-100.

211   Ian N. Gregory, *A Place in History: a Guide to using GIS in Historical Research* (Oxford and Oakville: Oxbow Books, 2003).

212   Donna J. Peuquet, "It´s about time: a conceptual framework for the representation of temporal dynamics in Geographic Information Systems," *Annals of the Association of American Geographers* 84 (1994): 441-461.

functionalities; traditionally, GIS have made approaches of the modelization of reality which are static since including the time factor greatly adds to the system's complexity. The temporal component cannot be dissociated from the spatial one hence the need for the Geographic Information Technologies to develop new spatio-temporal models and software that are capable of handling, exploiting and visualizing those data that comprise both components in a most efficient manner. Several authors already express the need for creating 'dynamics GIS' that can represent, analyze, and model geographic dynamics —reality is dynamic, not static—, and which are capable of handling more complex data sets[213] as well as give answers to spatiotemporal questions on objects and the information sets that define these objects, that is, their position, their time and their attributes. In this author's opinion, a dynamics GIS needs to make the connections across multiple themes and scales through spatiotemporal integration. One of the most recent proposals along these lines is what Pultar et al have denominated the dynamic GIS based on space time points.[214]

According to D. J. Peuquet a GIS that integrates the temporal component should be capable of answering questions of three different types – that referring to the object itself or spatial entity (e.g. 'where did merchant Mr. X carry out his commercial activity between 1737 and 1785?'); those related to the changes in the spatial distribution of the objects (such as 'along what routes did the Dutch frigate 'El Jacobo' travel between 1751 and 1755?'); and lastly those referring to the changes in the spatial relations among multiple

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213   May Yuan, "Dynamics GIS: recognizing the dynamic nature of reality. In GIS best practices: essays on geography and GIS," *ArcNews* 30 (2008), http://www.esri.com/library/bestpractices/essays-on-geographygis.pdf.
214   Edward Pultar, Thomas J. Cova, May Yuan and Michael F. Goodchild, "EDGIS: a dynamic GIS based on space time points," *International Journal of Geographical Information Science* 24 (2010): 329-346.

phenomena of a greater complexity (e.g. 'in the Indo-Pacific system, what was the relationship between the perception of the ports gained by the Europeans through the cartography at the time and the actual commercial volume at the ports used by the Dutch East India Company – VOC in the 17th century?'.

The efforts made for the last two years to integrate the temporal component in conventional GIS have focussed on addressing some of the following aspects in order to improve queries: *Spatio-temporal Data Model, query languages, geovisualization,* or *indexing*. But what have been the real advances for the last few years?

Regarding spatio-temporal data models, the majority of those proposed have been developed to solve specific issues, hence the difficulty to adapt them to address other issues. Conventional GIS have mostly used relational-database management systems for data management, but these have proven inefficient when handling space and time simultaneously. One of the major limitations lies in the inability for the relational model to understand "types", that is, combinations of simple data that conform a single unit, known as object. The development of spatio-temporal models involves including more complex objects as well as the handling of multi-dimensional concepts. The way ahead has been, then, the integration of time in Relational DDBB and then in Object Relational DDBB, which are more efficient in this regard. Mohd Rahim et al have carried out a review of the main models and a comparative analysis that comprise nine of them:[215] GEN-STGIS, Cell Tuple Based Spatiotemporal Data Model, Cube Data Model, Activity Based Data

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[215]   Mohd Shafry Mohd Rahim, Abdul Rashid Mohamed Shariff, Shattri Mansor, and Ahmad Rodzi Mahmud, "A review on spatiotemporal data model for managing data movement in geographical information systems (GIS)," *Jurnal Teknologi Makluma*t, , 17 (2005): 91-100.

Model, Object Based Data Model, Data Model for Zoning, Object Oriented Spatial Temporal Data Model, Multigranular Spatiotemporal Data Model, and Feature-Based Temporal Data Model. A further proposal for a model has been made by Peuquet and Duan which is based on time as its organizational basis, and thereby intends to facilitate analysis of temporal relationships and patterns of change through time; its name is Event-based Spatio Temporal Data Model (ESTDM).[216]

Other research teams are making progress in the subject of *spatio-temporal visualization* treating it as a scientific discipline in itself. The space-time cube, as propagated by Hägerstrand and others,[217] is the first concept. Andrienko et al[218] review some of the approaches that are most widely used in the field of geovisualization of series of spatio-temporal data, and Andrienko and Andrienko[219] propose new developments that are a combination of fields such as cartography or statistics – the so-called *time* maps, which represent the values of a specific attribute at a precise moment but which have controls that enable the user to modify the time line and move to the desired moment in time. The evolution is visualized in a *map animation*, in map series that visualize in a common framework various theme maps in different time spots in order to compare them visually, or in *value flow maps,* which represent the evolution

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216   Donna J. Peuquet and Niu Duan, "An event-based spatiotemporal data model (ESTDM) for temporal analysis of geographical data," *International Journal of Geographical Information Science* 9 (1995): 7-24.

217   Torsten Hägerstrand, "What about people in Regional Science?," *Papers of the Regional Science Association* 14 (1970): 7-21.

218   Natalia Andrienko, Gennady Andrienko and Peter Gatalsky, "Exploratory spatio-temporal visualization: an analytical review," *Journal of Visual Languages and Computing* 14 (2003): 503-541.

219   Natalia Andrienko and Gennady Andrienko, "Interactive visual tools to explore spatio-temporal variation," in *Proceedings of the working conference on Advanced visual interfaces* (Gallipoli, Italy: ACM, 2004).

of a specific attribute throughout time in specific locations through the inclusion of charts in those locations. These are examples of approaches.

When an object's evolution is studied throughout time, its changes can be in terms of *geometry* – such as the modification of a region's administrative limits – which in turns modifies the object's topological relation to its neighbours; it can change in terms of position – when, for instance, an agent moves locations or a ship travels along a route; or it can change in terms of *alphanumeric attributes* – e.g. the change of an agent's administrative functions throughout time, or of his/her titles of nobility or neighbourhood[220]. On other occasions, changes imply modifying the combinations of those basic typologies, increasing the model's complexity, its analysis and representation, because all these changes have to be stored in the spatio-temporal database. Sometimes changes are referred to as *events.* Both space and time are continuous variables, but in order to be studied they must be simplified and divided into discrete units for ease of analysis; out of this necessity arise the concepts of scale and resolution.[221] The spatial side has been resolved cartographically, and in the case of the temporal component it is usually called granularity as it refers to the degree of detail with which we approach data, and it will always depend on the data collected and the purpose of the investigation.

By using a temporal granularity defined on a month-year scale and a spatial granularity defined in *kilometres* we will be able

220   Agnar Renolen, "Temporal maps and temporal geographical information systems" *Review of Research*, The Norwegian Institute of Technology, 1997.
221   Donna J. Peuquet, "It´s about time: a conceptual framework for the representation of temporal dynamics in Geographic Information Systems," *Annals of the Association of American Geographers* 84 (1994): 441-461.

to observe and represent data on a reference cartographic base through a spatio-temporal window defined by the user. Through this window a visualization will be possible of the maritime routes passing through a port in a certain moment in time as well as the goods transported or the roles played by the different agents on a trip. In order to facilitate this type of queries the model relies on a geographical-point table that stores the space coordinates and some temporal attributes on the tables of the model's main entities: stage, ship, agent, cooperation which provide the temporal coordinate. In DynCoopNet there are a number of observations related to the dynamics of an object (e.g. ship, agent) or object group (e.g. fleet, company) throughout time which show their *geospatial activity*'.[222] These are complex events and can be classed as stationary when the object does not change its position in time but does change some of its states or attributes (e.g. an agent carries out several relations of commercial cooperation with another agent without modifying the town where they carry out their trading activity); or as dynamic or mobile when the object modifies its position in time as well as perhaps its state (e.g. a ship on a route making stopovers where commercial exchanges are made changes its cargo of goods). The record of all the locations that an object has occupied over a period of time is known as *geospatial lifeline.*[223] The objects' movement can be modelled in various ways depending on the chosen granularity[224]. In this sense, the model proposed for integrating the

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[222]   May Yuan, "Toward Knowledge Discovery about Geographic Dynamics in Spatiotemporal Databases," in *Geographic Data Mining and Knowledge Discovery* eds. Harvey J. Miller and Jiawei Han, 2 ed. (CRC Press, 2009).

[223]   Mark, D., Egenhofer, M., Bian, L., Hornsby, K., Rogerson, P. and Vena, J., "Spatio-temporal GIS analysis for environmental health using geospatial lifelines" (paper presented at the 2nd International Workshop on Geography and Medicine, GEOMED'99, Paris,France, 1999).

[224]   Kathleen Hornsby and M.J. Egenhofer, "Modeling moving objects over multiple granularities," *Annals of Mathematics and Artificial Intelligence* 36 (2002): 177-194.

project's databases allows us to launch queries about the *geospatial* lifeline of each agent, commercial company, ship, etc. Each one of these objects has an identifier that defines it univocally during its whole life.

Data sources

Therefore the GIS will integrate, based on data from various researchers, three spaces clearly differentiated by their geographical localization and by their behaviour as commercial networks: the Spanish Atlantic of the Indies Trade and its links with other mercantile areas (DynCoopNet Crespo Database), the Indo-Pacific Trade System (DynCoopNet Picazo Database), and the financial system of the Hispanic Monarchy (DynCoopNet Alonso Database); each one placed in specific time frames. All gathered data are linked to a spatial location as much as to a specific moment in time.

The integration of independent historical data sets in order to make global analyses that provide new knowledge in relation to trade in such a vast period of time – 15th to 18th centuries – has posed a number of technical and conceptual problems. Firstly, when the data were originally collected there was no intention of integrating them into a GIS, which means that no geographic coordinate was collected of the entities capable of being georeferenced – ports, cities, stopovers, etc. This task has been undertaken at a later stage. As far as the temporal component is concerned, in historical research there exists the concept of temporal indeterminacy for the case of an event than cannot be assigned to a specific moment in time. On other occasions temporal references in source documents are

expressed in natural language and are therefore unintelligible to computers. A further problem is the fair degree of uncertainty that historical sources have where information gaps make it difficult for the later analysis of data. If there is one thing that defines all three databases that have been integrated in the proposed model, that is their high degree of heterogeneity; each one was compiled by historians with a specific, independent scientific aim and by using different IT tools (text documents, spreadsheets, database management systems, etc.). This has led to a great effort being made to develop a single model that is common to all of the original DDBB, as well as to develop a platform (DynCoopNet Data Provider) through which historians are able to migrate their respective data from their own systems to this new, proposed one (Fig 1).
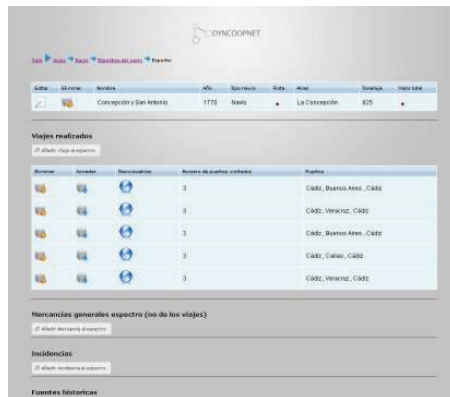
Fig 1. Graphic interface of the DynCoopNet Data Provider application. It facilitates data migration from their original format to the new system's single data model.

Here follows a detailed description of the contents and the original compilation process of one of the three DDBB integrated so far in the model – DynCoopNet Crespo Database, with information on the Atlantic and its connection with other areas, such as the Caribbean.

The Spanish Atlantic of the Indies Trade Database (DynCoopNet Crespo)

This database contains information on commercial individuals, their relations of commercial cooperation, and ships, where most of this cooperation took place within a specific chronological framework (1648-1778) and a wide geographical framework (e.g. a ship could set sail from Gothenburg and stop in Cadiz on her way to Manila).

The choice of sources used for compiling the massive amount of information stored in this database has been central to the process. As we are aware that not all information available in the sources can be collected, especially that on archival sources, only the information relevant to this investigation[225] has been chosen as a greater amount of information does not necessarily guarantee the success of the research.[226] A great variety of documents have been used although they all have in common their reference to commercial agents – all documents have been consulted provided that there is a reference to an agent participating in a commercial activity or cooperation, be it legal or not. Specialized works on merchants have been used as well as more general works, together

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225   Francisco Fernández, "La Historia Moderna y Nuevas Tecnologías de la Información y las Comunicaciones," *Cuadernos de Historia Económica* 24 (2000): 11-31.
226   Jean Pierre Dedieu, "Un instrumento para la historia social: la base de datos Ozanam," *Cuadernos de Historia Moderna* 24 (2000): 185-204.

with original documents dating back to the 16th, 17th and 18th centuries, such as registers of outbound and inbound trips of fleets, lists of passengers to the Indies, registries of merchants, seafaring dictionaries, etc. In the process of source selection specialist authors were consulted[227] as well as the NACOM bibliographic repository, which is kept constantly up-to-date.

The first premise for selecting sources was primarily that they contained data on relationships among merchant communities, and secondly that they featured biographic as well as professional information on the agents that formed part of those communities or were somehow related to them. The same agents can appear on different sources, which make it complex to identify them as they can be easily mistaken for someone else who bears similar first or family names. This difficulty could lead to data duplicity or even to the input of contradictory information (e.g. one agent could be called *White* in Amsterdam and have his name changed to *Blanco* – Spanish for White – when settled in Cadiz. Other historical databases have also been consulted which deal with commerce-related topics, such as 'The Trans-Atlantic Slave Trade Database'[228], 'The Soundtoll Registres'[229], the Colegio San Telmo database in Sevilla[230], and the 'Van Johannson database for 1784-1800'[231]; Further, unpublished ones have also been consulted as well as others compiled by our contributors. They all deal with trade, trips and agents, although

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227   Enrique Chávarri and Jesús Sobrón, "Base de datos histórica a texto completo" *Revista General de Información y Documentación* 4 (1994): 165-186.
228   Vid. Ut supra chapter 3.
229   http://www.soundtoll.nl
230   Marta García Garralón, *Taller de Mareantes: El Real Colegio Seminario de San Telmo de Sevilla* (1681-1847), 2 vols., Sevilla, 2007.
231   Cf. Werner Scheltjens, "The volume of Dutch Baltic shipping at the end of the eighteenth century: a new estimation based on the Danish Sound Toll Registers", http://www.rug.nl/staff/w.f.y.scheltjens/SCHELTJENS_ICHS_paper.pdf

they are all peculiar in their own way. Classic works[232/233] containing lists of vessels and agents have been used too. Original data were stored in an Access® database. Its main structure hinges on the primary table, named *AGENTES*, where the individuals', or agents', biographic data are stored taking into account the various worlds they belong to, be them social, economic, etc, as expounded by Jean Pierre Dedieu[234]

A study and an individual classification have been done so that a later understanding of the collectivity can be gained based on the sum total of individuals since, as can be gathered from the database, such individuals were related to each other, as ratified by Bernd Hausberguer[235] and Jean Pierre Dedieu[236] - even though one merchant is settled in Veracruz and another in Antwerp, the networks bring them together under communication, which means that this study arises from Prosopography. In relation to agents, what is new about this early database is that the research conducted did not limit itself to the merchant profession but tried to encompass every relevant piece of data related to every agent involved in cooperation, such as representatives, corsairs, pirates, capitalist partners, agents, consignees and brokers, etc. All these are agents participating in cooperation and who are part of a global network involved in trade, contraband, looting or any other cooperation or commercial activity found in the sources.

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232   Pierre Chaunu, *Seville et l´Atlantique*, 1504-1650, (Paris: Librairie Armand Colin, 1955).
233   Michel Morineau, *Incroyables gazettes et fabuleux métaux. Les retours des trésors américains d´aprés les gazettes hollandaise*, (Paris: Cambridge University Press, 1985).
234   Jean Pierre Dedieu, "Les grandes bases de données: une nouvelle approche del´histoire sociale. Le Systeme Fichoz," *Revista da faculdade de Letras HISTORIA*, 5. Serie III (2004): 101-114.
235   Bernd Hausberger, "La conquista del empleo público en la Nueva España. El comerciante gaditano Tomás Ruiz de Apodaca y sus amigos, siglo XVIII" *Historia Mexicana* 56 (2007): 725-778.
236   Jean Pierre Dedieu, "Un instrumento para la historia social: la base de datos Ozanam," *Cuadernos de Historia Moderna* 24 (2000): 185-204.

A second table named *COOPERACIONES* was set up where all ways of possible commercial relationships between agents were input, such as business, Company, Society, etc. What is new about this database is that every type of goods exchange – whether legal or otherwise and in slaves, metals or other commodities or merchandise - where two or more agents are involved has been included in the table. The aim is to be able to track any types of commercial networks, hence the fact that agents are not only individuals but also societies, institutions, companies etc.

A further table called *ACCIONES* was created where all actions and activities – lending, representation, etc – that occurred within the framework of any relations of cooperation were recorded when the historic source provided details on them. This table was linked to a further weighty one, that of *NAVIOS* –vessels. By means of using the information related to every ship based on the various trips in which the ship was involved, together with the study of the relationships among the various agents that participated in those trips, a number of cooperative networks have been identified.[237]

Many of the original Access® database's remaining tables store typologies such as places, professions, etc. Choosing the four aforementioned tables as primary – *AGENT, COOPERATION, ACTION and VESSEL* – enables us to analyze the various relations among agents at commercial, professional and interpersonal levels, placing great emphasis on their geographic location, their chronologic moment and their degree of kinship, thus defining the cooperation networks formed by those agents – such as the importance as a merchant of Nicholas Magens, or the relevance

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237   Jeroen van der Vliet, "Watching the Ships Sail Out. Linking Shipping Data from Amsterdam and the Baltic" (paper presented at the Sound Toll Registers, First proof, Groningen, June 10-11, 2010).

of such families as the Roos or the Amsicks whose influence could span from Elche to Alicante (two towns very close together) or from Cadiz to Manila via Mexico-Tenochtitlan.

A crucial aspect of the data used is their temporal component. In the majority of cases two different fields were allocated, one in data format and a second, text-format, one, for when the source did not provide a precise date or this was inconclusive, as indicated by Jean Pierre Dedieu.[238] The same situation exists as far as the spatial component is concerned; two fields were set up, one to store the name of the place and a second one for any relevant remarks, such as 'transitory stay in Cadiz', or when we know the old name of the place but not the current one. However, in the original database geographic coordinates – longitude and latitude - were never recorded. In relation to this component, the geographic range of this project is something new, original. Despite being based on the Atlantic area, once the sources were consulted – specially those referring to trips and family and commercial relationships, the networks spread out into the Mediterranean, the Pacific and even the Indian Ocean – this is particularly true when the agents under study are pirates. The importance of this is that despite starting from one pre-defined spatial range, there has been no restrictions in terms of the area covered, thus highlighting the importance of the cooperative networks that developed in the era under study as well as the high degree of globalization attained.

The field notes and sources can be found in every table so that every record is furnished with its own remarks and source citation. Even in the tables that simply contain typologies there

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238   Jean Pierre Dedieu, "Un instrumento para la historia social: la base de datos Ozanam," *Cuadernos de Historia Moderna* 24 (2000): 185-204.

are fields for notes and definitions for those obsolete, disused or simply unknown terms, in order to assist understanding in the face of doubt and uncertainty.

Indo-Pacific Trade System Database (DynCoopNet Picazo)

This database stores an enormous amount of information related to commercial networks, ports and maritime routes in the Indo-Pacific area during the First Global Era (1400-1800). Trade relations of the various ports of the Mediterranean to the Indian Ocean during the late Middle Ages show that from 1400 we can speak of a true first global age. The economies of both areas were completely interlinked, cooperating with one another with a common purpose: the increase in business and the spreading of commercial networks to supply markets.

From the data integrated in the GIS the system will analyze the commercial development of the Philippines, its main ports supplying the various "forelands" that were connected to Manila, according to that classic definition of Weigend.[239] We will also study what was structured as hard mercantilism of the metropolitan authorities of the Hispanic Monarchy, the coercion that was performed on the merchants and residents in Manila and the reason for it. We will present in detail the connections with other areas in the Philippines, the economic dynamics that followed trade, its evolution and, indeed, the changes suffered. Some of the data stored in the database are: boats and skippers, nationality of

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239   Guido G. Weigend, "Some elements in the study of port geography," *Geographical Review* 48 (1958): 185-200.

the port of origin, goods, type of products (silk, iron...), the value of the load, cooperation and collaboration aboard the ship, and so on.[240]

The objectives pursued through the integration of this database in DynCoopNet GIS are as follows.

• Create a database of ports.

• Make a database of the Philippine trade relations with the ports in the Indian and Pacific Oceans.

• Linking the ports to their respective historical cartography, whenever possible.

•Explore the visible collaboration and cooperation (legal trade) and the invisible one (illegal trade).

• Analyze the Europeans' perception of distant markets and their main ports, comparing the ports depicted on the historical maps with the ships recorded in the database related with the EIC (East India Company) and the VOC (Dutch East India Company).

• Analyze the importance of a specific port – Manila - between 1600 and 1700: products, traders, values, and ports of trade.

• Analyze the epistolary relations between the agents from the EIC and the VOC in order to understand how the information flow was devised and evolved among agents settled in Asia, as well as how the various networks were structured and the level of activity sustained between the various members of the network and with the companies' central offices.

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240   Cf. Chapter 8 of this book.

Financial System of the Hispanic Monarchy Database (DynCoopNet Alonso)

This database contains information related to power and the tax system in Modern-Age Spain – 16th century. It was originally built in Access® format. It is basically a database with extensive information on high-rank people that had dealings with the treasury, such as fiscal officers, collectors, lenders, factors, etc. The geographic location assigned to these agents – essential for their GIS inclusion – was determined by the places they lived in but also by the places in which they carried out their professions.[241]

At the time of collecting information great importance was given to the storing of personal relationships or links among all these agents as well as their commercial dealings; among other things, the kinds of taxes they levied – sales tax, customs duties, tolls, tithe, etc – or the relationship's typology – debtor, financing partner, creditor, owner, etc. Each agent's historical professional record throughout time and space has been stored – hence the combined spatio-temporal component; and, among others, titles of nobility, professions undertaken, official posts held, administrative positions held, their states (and their states' source, such as purchase, inheritance, donation, etc.) have also been specified. To sum up, in this database the study of the individuals and their relations are on the foreground. And in order to extensively analyze such complex social networks, a great deal of data has been stored on the epistolary relationships among the various agents and institutions at the time – e.g. the Royal Council of Castile, the *Contaduría Mayor*

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241   Cf. Chapter 7.

de Hacienda (Treasury's Accountancy Agency), etc. The following are three of the scientific objectives pursued with the implementation of this historic GIS.

• Creation of a complete registry of the evolution of the agents' income throughout time.

• Analysis and visual representation of cooperative interactions between agents as well as trade flows and network dynamics.

• Analysis of the relation between the commercial activities of the financial system in the Hispanic Crown in the 16th century, space – a wide geographic range – and time.

Conceptual model for spatial and temporal historical data: design and implementation

The approach from which the DynCoopNet system has been designed is that of Software Engineering, which is an IT discipline that offers methodologies and techniques for developing and maintaining high quality software.

The model utilized for developing the needed software is the spiral lifecycle one. This model represents the various development stages in cycles. Each cycle means a milestone within the project; for instance, the innermost cycle may refer to the systems' feasibility, the following cycle out would be the definition of requirements, next would be the designing of the system, etc. Each cycle is divided into four sectors or phases.[242]

• Definition of main objectives.

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242   Ian Sommerville, *Ingeniería del software* (Pearson Educación, 2005).

• Risk assessment and reduction through careful planning.

• Development and validation: once risks are indentified the appropriate model is followed for the development of the system.

• Planning: the project is reviewed again and a decision is made to move on to the following stage.

The design of the model has been done by means of successive approaches, by technicians and historians working in close collaboration, with the objective of defining the scientific necessities of the latter so they can be transferred to the conceptual model. Periodic interviews and working sessions have been held in order to outline the functional requirements, that is, the list of operations the system should handle as well as the questions it should answer, as far as possible. With this feedback a prototype has been designed that will grow and be modified as meetings progress. Once a stable model has been achieved, that is to say that there will be no longer new functional requirements, a prototype has been created that has to be validated by the user in order to assess if the model really fulfils the initial functional requirements.

Within the typologies of data models we have chosen for this project one of the most popular models - the so-called *entity-relationship model* (ERM)[243]. It is a conceptual data model – also called semantic model – used for representing data structures within a system. It is thus named because it displays data in terms of entities and relations defined by those data.

In order to arrive at an ERM several previous stages must be completed.

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243   Peter-Pin Chen, "The Entity-Relationship Model: Toward a Unified View of Data" *ACM Transactions on Database Systems* 1 (1976): 9-36.

• Identify the system's prerequisites through the so-called *use cases*.

• Fulfil the use cases that have been identified by describing the classes or entities that support those cases; such entities can be *control, entity* or *interface*, depending on their semantic purpose within the system.

• Lastly, the data model is obtained by following certain transformation rules – *metric 3.*

Data are fed into the GIS; but in order to gain access to those date they have to be modelled into a specific physical structure through an ERM. Therefore the future operation of the GIS will be directly linked to the quality of the system's data model previously designed, hence the crucial significance of an efficient design.

One of the design stages of the ERM is the normalizing of the database, which consists in applying a series of rules in order to ensure data integrity through the prevention of data redundancy and/or duplicity. In DynCoopNet data model data normalization complies with Boyce-Codd Normal Form – BCNF[244] in order to reach thorough control over data and thus ensure the system's quality and of the end result.

The referential integrity has also been designed to ensure that the relationships are safe in the event of deletions or alterations on the database as these can affect the logical integrity of the model. In this sense, the model has been provided with classification tables, which hold first and last names, ship typologies, merchandise types, etc. This kind of tables allow the user to verify whether the record he/she is trying to insert is unequivocally in the database or not,

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244   Cristopher J. Date, *An Introduction to Database Systems* (Addison-Wesley, 2004).

thus allowing the detection and prevention of an incoherence (for example "Hannah" is different from "hannah").

The model's spatio-temporal dimension

As previously explained, the model that has been developed comprises both the spatial and the temporal components. The former is located in the table named geographic location, which table provides, under *PostGIS*, the basis for geo-referencing geographic entities of a point or polygon type (zones). This module adds support for geographic objects to the Object- Relational Database that has been chosen to store data in this project - *PostgreSQL*[245]. This spatial module has been chosen as it has been certified by the Open Geospatial Consortium (OGC), which guarantees its interoperability with any other interoperable systems.

The model's main entities – agents, ships, companies, etc – are related to specific geographic locations (Fig 2). The temporal component is attached as an attribute field to certain entities with an annual granularity for the temporal range of the historical analysis – 1400 to 1800, thus enabling it to be
utilized in the data analysis as one mere variable just as the spatial component is in the studies usually conducted with GIS.

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245   Stephan Holl and Hans Plum, "Powerful GIS Functions in the Database System PostgreSQL. PostGIS," *GeoInformatics* 12 (2009): 34-36, http://fluidbook.microdesign.nl/geoinformatics/03-2009/#0.
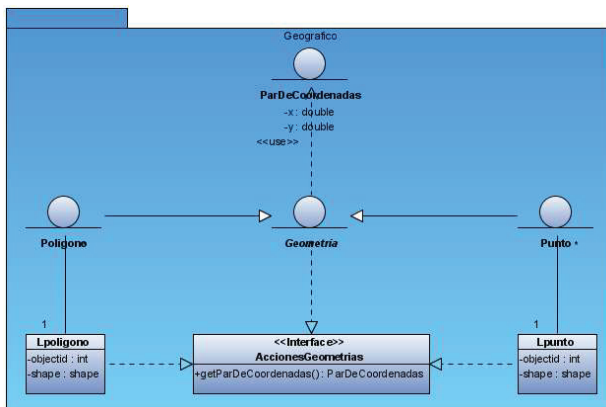
Fig 2. UML diagram showing the model's spatial component

Model components

The physical model presented by the GIS-DynCoopNet links two large blocks of historical information compiled from very heterogeneous sources: on the one hand the life-cycle of the ships involved in the commercial operations at the time, which includes every single trip detailing port of departure, stopovers and port of arrival as well as the commercial transactions carried out on each of those ports and the incidences that took place on each trip; and on the other hand the cooperation relationships established by the different agents in specific geographical places – *agents* here are either private individuals that established various forms of association forms, or large monopolistic companies (Fig 3).

Both blocks are correlated in the model, which will allow subsequent analyses that will open new perspectives in the

understanding of the behaviour of these self-organizing networks. Such analysie will respond questions in specific geographical spaces (the GIS will integrate three spaces clearly differentiated by their geographical localization as well as by their behaviour as commercial networks: the Spanish Atlantic of the Indies Trade and its links to other trade areas, the Asian merchant system and the routes of the Asian southeast ocean, and the financial system of the Hispanic monarchy) and in specific temporal moments.

The conceptual design therefore emphasizes the relationship between the previously specified information blocks. This way the system is able to detail the cooperative relationships among the agents that played different roles within the large monopolistic companies or in the private societies created by the agents and which showed, on occasions, relations among them. Such relations showed a connection between those trading activities with the movements of the ships at the time in the various systems and subsystems, the cargoes transported or the incidents occurred on each marine route.

Based on the captures of requirements and by applying standards and algorithms a scheme has been obtained with 56 normalized tables. 22 out of these 56 are apt to logically connect the records whereas the other 34 contain types and entities that typify and build the model's pillars.
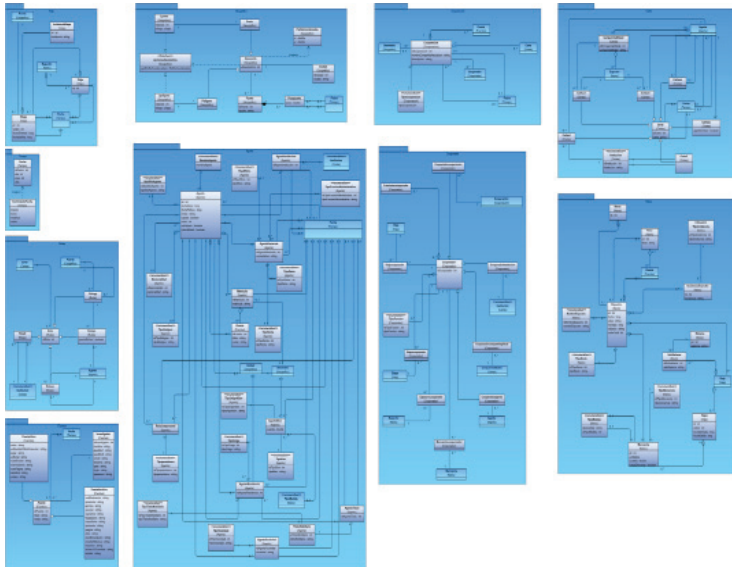
Fig 3. Conceptual Data Model of GIS DynCoopNet in UML notation

Now we are going to describe the data model in detail:

One of the two main blocks of the model is the *ships* one. The trading history of each one of them is conceptualized in what has been denominated *spectrum*, which refers to a ship's state in a specific moment in time and in a specific location (spatio-temporal component of the GIS) (fig 4). This will allow us to follow up on a certain ship on each and every one of the commercial trips it was involved in, as a result of the different *cooperation relationships* (grey) established among diverse agents, whether at individual level or as global monopolistic companies. Among other capabilities, this

will enable us to visualize in the GIS over a base cartography the routes followed by the various ships or the fleets those ships were part of, the incidents that occurred, the volume of traded goods, etc.
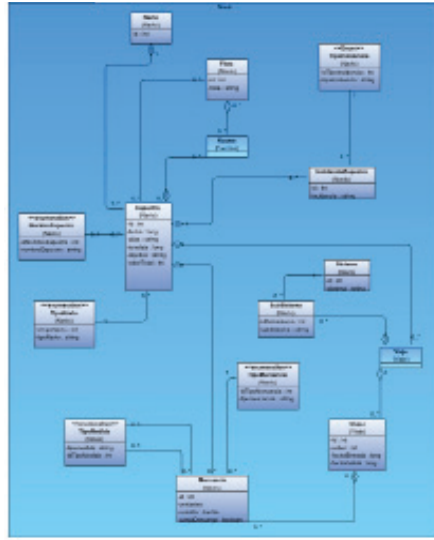
Fig 4. Data model: block 'ships', components and relationships

The model's second great block is the *agents* one and the information related to them (Fig 5): family relationships with other agents, religious confession, residences where they developed their commercial activity, positions occupied, institutions they worked in, and even the *epistolary relationships* (blue) maintained with other merchants, etc. The design in this block has been devised to be subsequently capable of describing and representing the cooperation relationships among the different agents in specific

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geographical locations (pink).
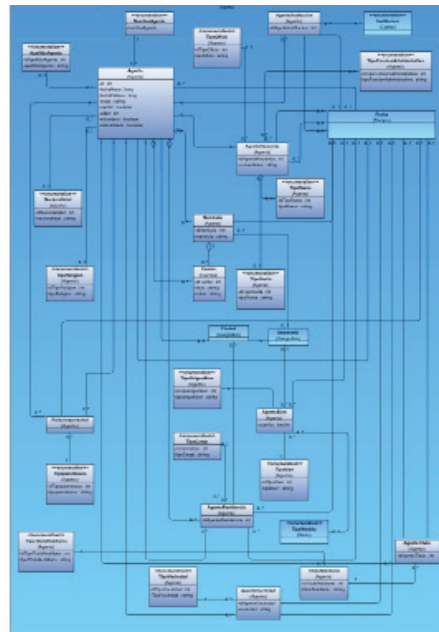
Fig 5. Data model: block 'agents', components and relationships.

The two previously presented blocks are connected through what has been denominated *cooperation*, commercial relations among agents (Fig 6). An agent is in fact a merchant that, either he/she temporarily associates with other agents for a specific commercial dealing materialized in the trip of a ship loaded with certain goods (and with some specific epistolary relationships on occasions), or they belong to one of the existing large global monopolistic companies in the period under study; either way this

agent plays a certain role in that commercial relationship (factor, agent, master, loader, etc.). This block is the central axis of the data model, establishing the relationship between the two previous large blocks: *ships and agents*.
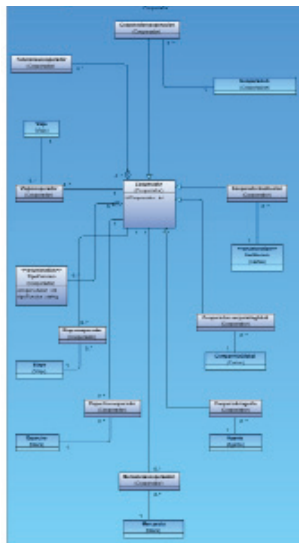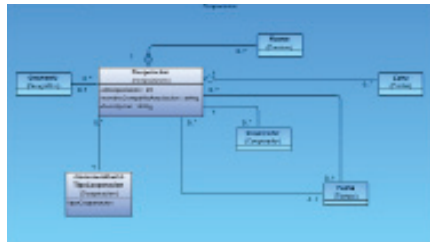
Fig 6. First: Ships and agent Relational Data model. The Second Figure: Data model: block "cooperation" and "cooperator", component and relationship.

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There are various ways to incorporate the temporal component into a database. In the present case time is a mere attribute of the entity or geo-referenced objet – i.e. the port of departure on a ship's specific route has a specific date attached, or an agent carries out a specific administrative operation in a town between two dates, or a letter arrives at its destination on a specific date, etc. By doing this an analysis can be conducted on the networks, modelized as relations of cooperation or ships' routes, in a defined time period, or their evolution within that period – for instance, cities or ports where commercial activity is focussed, influential merchant families, kinship relationships between agents located in defined geographic spaces, etc.

Social Network Analysis

The network analysis is the area responsible for analyzing networks based on the network theory, usually known as graph theory.[246] Networks can be of various types. As far as DynCoopNet is concerned networks are of a social type and are made up of sea trips of ships, of merchants and companies, and of the commercial relations established among them thus creating a whole, huge cooperation network.

Within the designed data model all entities are related. Ordinary entities representing ships, agents and trips, etc, are space located by means of the entity Lugargeografico, whereby analyses and studies can be conducted by using the spatial component. Entities named puerto, residencia, agente or ciudad are related

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246   Robert A. Hanneman and Mark Riddle, *Introduction to social network methods* (Riverside, CA: University of California, Riverside, 2005).

to entity punto, which means that these entities have geographic semantics.

From this definition of a detailed model, the development team will endeavour to use tools, algorithms or mathematical models in order to obtain information and study the reality offered by the modelled data. There exist a number of models and algorithms that can be applied to obtain information on networks; they range from the fundamental, such as *Dikstra, Kruskal, cover trees*, etc[247], to *artificial intelligence* algorithms, such as A* search or heuristic search algorithms.[248]

A clear example of integration and use of these geographic entities in data modelling is the study of sea traffic between ports. Fur such a study we use the ships' stages along their routes; we count them up in order to obtain the port's weight. A traffic network can be viewed as represented in a weighted directed graph.

The charts below show two networks – one (Fig 7) depicting sea traffic between ports, and another (Fig 8) displaying relations among agents. On the basis of the proposed model various types of networks could be superimposed in order to obtain additional information on the phenomenon of cooperation.

247   Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein, *Introduction to algorithms* (Cambridge: The MIT Press, 2001).
248   José Mira, Ana E. Delgado, Jesús G. Boticario and Francisco J. Díez, *Aspectos básicos de Inteligencia Artificial* (Madrid: Sanz y Torres, 1995).
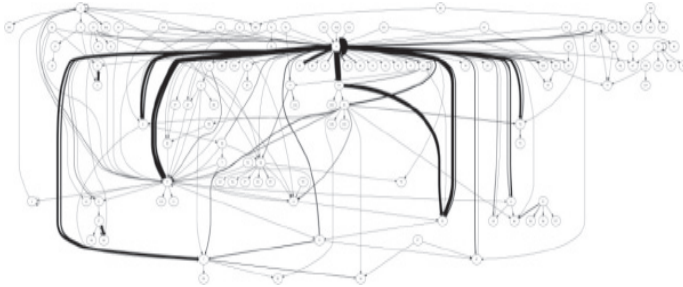
Fig 7- It shows maritime traffic between ports where ports are represented by their identifiers.
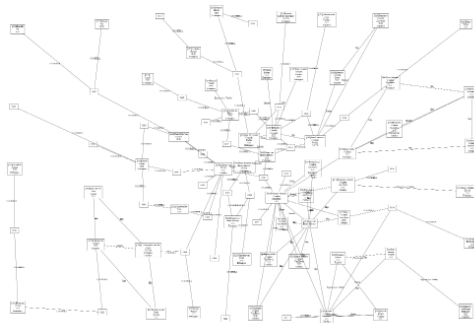
Fig 8 - It represents the relations (lines) among various agents (squares). The relations' notation specifies whether the relation is of kinship or of a commercial nature.

Due to the model providing a vast amount of information on ships, routes, ports, agents, relations of cooperation, etc, the need arose for designing and implementing an optimal subsystem responsible for handling all this information and exploiting the networks that make up the sub-system of networks together with the

model of analysis. The software under this subsystem is snGraph, and has been liberated under Attribution-NonCommercial 3.0 Unported Licence.[249]

This system stores internally the data in a *hash table*[250] with pointers in linked lists which, in turn, have vectors holding weights and relations. This information held by the system can thus be easily exported to other systems, such as the social network analysis program, UCINET.

The following is one of the typologies of graphs than can be generated – Fig 9.
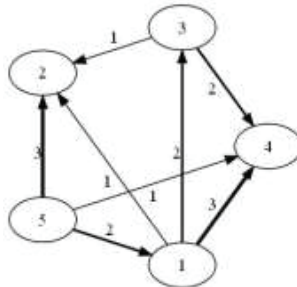
Fig 9 – It depicts the relations (lines) among entities (ellipses) and
their weights (cardinality and thickness of the lines)

The above graph is internally stored in the system with the following data structure, in which the red-dotted squares refer to the entities (ellipses in graph above) and the unbroken lines give a picture of the relations and their weights.

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249   Roberto Maestre, *snGraph. Software óptimo para manipulación de redes libres de escala,* http://digital.csic.es/handle/10261/27556 (acessed November 29, 2010).
250   Donald E. Knuth, *The Art of Computer Programming: Sorting and Searching* (Addison-Wesley, 1998).
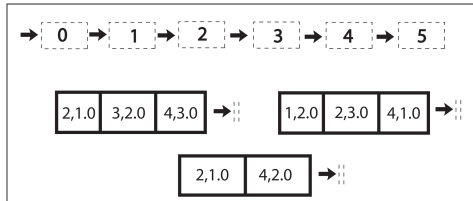
This format is easily exportable to UCINET[251] software in the following way.

```
dl n = 5 format = edgelist1, y

data:

1 2 1.0

1 3 2.0

1 4 3.0

3 2 1.0

3 4 2.0

5 1 2.0

5 2 3.0

5 4 1.0
```

In the scheme above the first digit is the entity's identifier, the second is the identifier of the related entity, and the third represents the relation's weight; the latter could refer, in a real-life analysis, to any variable to be studied, such as the number of times the ship calls at a specific port, the volume of a particular

251   Steve Borgatti, Martin Everett and Lin Freeman, UCINET, http://www.analytictech.com/ucinet/ (acessed August 31, 2010).

good sold in a city, or the number of letters exchanged between two agents. From this array representations of the following type are automatically generated – Fig 10.
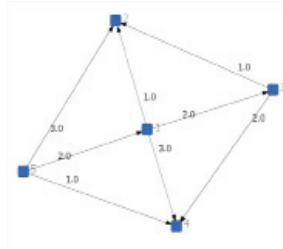
Fig 10 – Type of graph generated by the UCINET software using snGraph conversion.

The following shows a complex model of cooperation between agents by the use of commercial companies and relations of kinship as analysis variables in the network – Fig 11.
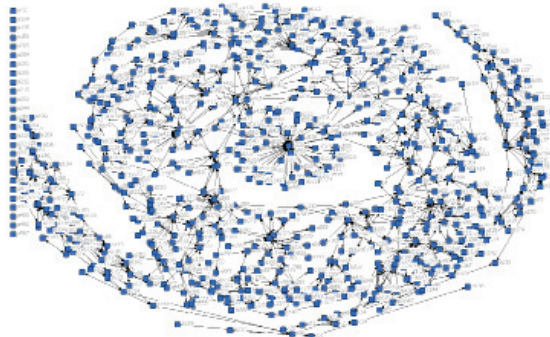
Fig 11. Representation of the network generated from data on agents and their commercial relations.

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Currently work is being done to combine traditional GIS tools with this specific type of software that generates these forms of network graphs so nodes in the network are shown in their specific geographic location - the nodes could be the cities where agents conduct their commercial operations, or the ports of departure for ships, or the destination of epistolary correspondence between agents – and lines link points that are related in that network. This way the spatial component will be visually integrated into the study, thus reaching an important milestone set by historians for DynCoopNet.

Geovisualization tools

The final objective of GIS is to obtain derived knowledge from spatiotemporal relationships and behavioural patterns of self-organizing networks in the First Global Age. It will also be able to detect high-priority trading areas; analyze the effectiveness of each of the networks in socioeconomic terms; identify which sociological mechanisms among agents helped to sustain high cooperation levels (commercial associations, family relations, religious confessions, patronage and sponsorship...) and facilitated the exploitation of certain commercial areas instead of others; and depict the evolution of these networks throughout five centuries of history.

With the first data integrated into the proposed model various geovisualization methodologies are beginning to be used. Representation of spatiotemporal data is a complex issue and is a current technical challenge within the world of GIS. Here follows

some of the approaches tried so far.

The use of time-lines to represent the various events since each one of them has a specific direction determined by the start date and the end date. Every event means a change, whether in the object's location, the contents of its attributes, or the way it relates to its neighbouring objects (topology). It is also a dynamic transformation that needs to be depicted as well as the progress of time. In this sense, it is being considered the use of the ESRI® ArcGIS... Tracking Analyst extension, which allows for the visualization and analysis of temporal data by defining events, including time, location, and attribute information. ArcGIS Tracking Analyst enables us to explore, visualize, and analyze information relative to time, location, and change. It provides capabilities for the sophisticated visualization and analysis of time-related data by defining temporal events that consist of the following information: time (the date and time of the event), position (the geographic location of the event), and attributes (object-specific characteristics and properties). ArcGIS Tracking Analyst (Fig 12) extends the ArcGIS Desktop with time series and real-time visualization of change.[252]

With this type of geovisualization tools data are circumscribed to a time line and a specific spatial location, breaking away from the traditional way of representing events in independent layers and thus greatly increasing the analysis potential (Fig 12).

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252   ESRI. 2004. ArcGIS 9. ArcGIS Tracking Analyst Tutorial, http://webhelp.esri.com/arcgisdesktop/9.3/pdf/Tracking_Analyst_Tutorial.pdf (acessed July 31, 2010).
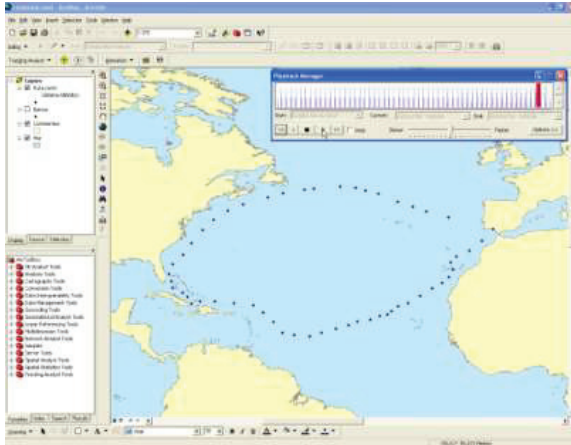
Fig 12. ArcGIS Tracking Analyst showing a time-line and a maritime
commercial route in the 18th century.

Various other ways of representing spatiotemporal
geography with the project's data. Several previous experiences
have used the so-called *space-time cube*[253] in which there are
threedimensional axes where *x- and y-axis* are the flat spatial
coordinates and the vertical *z-axis* represents time. In this cube
when the object's location remains invariable throughout time it
is represented by a line perpendicular to the *xy* plane. The team
of Spanish GIS experts within DynCoopNet have been conducting
preliminary trials with an extension of the ESRI ArcGIS®
sortware developed by the University of Tennesse in this line of
visualization.[254] With this extension, users can visualize tracking

[253]   Torsten Hägerstrand, "What about people in Regional Science?," *Papers of the Regional Science Association* 14 (1970): 7-21.
[254]   Hongbo Yu and Shih-Lung Shaw, "A Custom Extension of Extended Time-Geographic Framework Tools in ArcGIS" in *Towards a GIS-based Analytical Time-geographic Framework for Physical and Virtual Activities* (2006) http://web.utk.edu/~sshaw/NSF-Project-Website/ (acessed april 15, 2010).

data at individual level (e.g., survey data of individual locations over time such as migration history data, or commercial routes) in a space-time GIS environment. In addition to the space-time GIS visualization tools included in this extension, they have developed exploratory spatiotemporal analysis functions based on an extended framework of Hägerstrand's time geography for studying individual activities in both physical and virtual spaces (Fig 13).
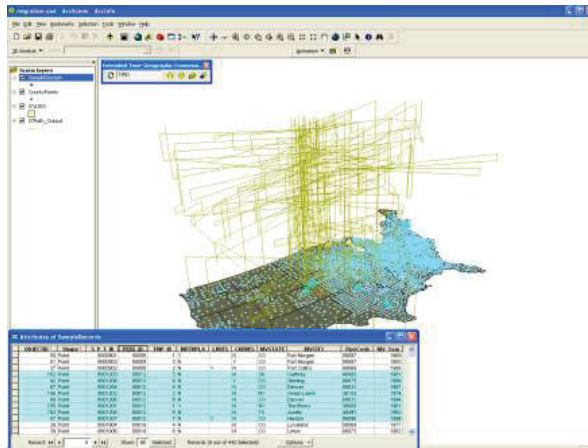
Fig 13. Interface and representation of example data by the FREE "Extended Time-Geographic Framework Tools Extension" for ArcGIS 9.3.

A further type of representation very useful when depicting any types of network is the so-called spider diagrams (Fig 14), in which the GIS incorporating them displays as dots the related entities – ports, cities, etc – and as lines the relations established among the entities regardless of the type of relation or variable being represented.
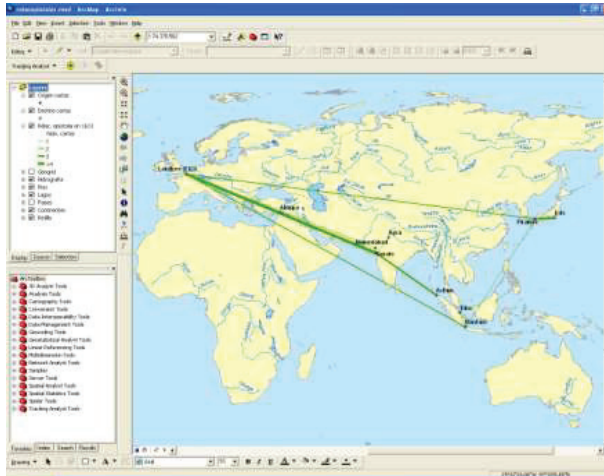
Fig 14. Representation by means of '*spider diagrams*' of the epistolary relations among agents located in various cities over a specific time period. The thickness of the lines represents the number of letters exchanged. This representation is done on a free-access extension for ArcGIS 9.3.

Further to the representation of social networks or the creation of interactive, dynamic maps integrating the temporal component, there is a type of representation very useful to researchers – the traditional thematic maps analyzing a specific alphanumeric attribute (Fig 15). In this line, the potential offered by GIS when it comes to making the most of such complex and dense DDBB is unparalleled.
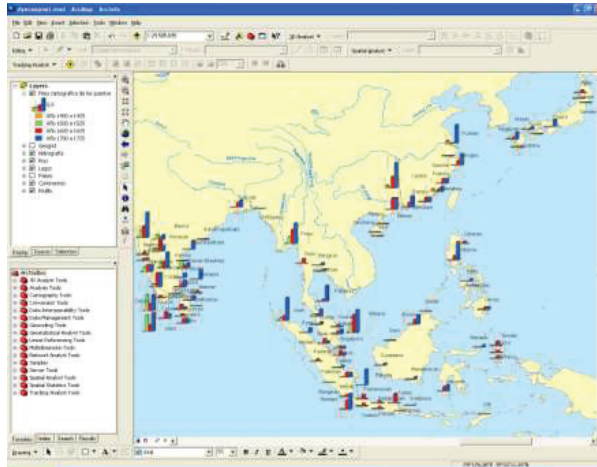
Fig 15. Thematic map done with ArcGIS 9.3 representing the Indo-Pacific system which shows the evolution of spatial perception -15th to 18th centuries – through the allocation of cartographic weights to the ports in diverse periods.

Conclusions and future

The GIS applied to historical research under development within the framework of the DynCoopNet project will implement the spatiotemporal component with the ultimate aim of conducting the analysis that will shed light on the functioning of the self-organizing social networks in the First Global Age, on the patterns of behaviour that governed and sustained these networks and ensured their success, on the interactions that occurred among the entities that formed these networks, and on how the changes in

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some of them had an impact on the rest.

The Spanish Atlantic of the Indies Trade Database (DynCoopNet Crespo) as well as the DynCoopNet Data Provider interface are currently hosted in the Digital Repository of the CSIC - (http://digital.csic.es/). The latter will be used in a local environment at this early stage in order to facilitate the integration of the DDBB mentioned earlier in this article, thus feeding the GIS that will handle the available information in an integral way through powerful tools for spatiotemporal analysis and visualization.

This ability to create knowledge that is derived from an objective analysis of the data collected by various researchers from different historic sources is a feature of the GIS. The future endeavour is to a) develop further, more flexible, spatiotemporal conceptual models that allow the system to self-feed with future data from further sources, b) design more efficient and user-friendly software tools, c) create more efficient query languages and/or geovisualization methods that make for greater ease of interpretation of the results, d) in short, develop new technologies that are capable of responding to these types of questions where an interrelation exists between time and space.

Once the conceptual and methodological hurdles are overcome which imply approaching the historical issues from an integrated spatiotemporal perspective, the future will require the development of new tools allowing the interoperability between several historical sources whose themes and time ranges are similar. This means focussing the attention on the high potential of the Spatial Data Infrastructures (SDI) to share geospatial information within a common framework. The harmonization

and interoperability between systems is a very complex issue, and this complexity greatly increases when the temporal component is added. Hence the highly ambitious approach to the future challenges in this field.

Self-organizing: The Case of merchant Cooperation in the Hispanic Atlantic Economy (1680-1778)

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A New Experimental Method in an Old Historic Framework

The aim of this article is to offer some examples of possible use cases in the representation and study of mercantile networks focusing on the analysis of various types of cooperation between people that has emerged in response to specific demands of businesses. Certainly, as Eric Van Young indicated in his conclusion to an anthology of texts, the study of networks is overwhelmed by the huge quantity of compiled empirical data but still lacks a level of conceptualization that can truly serve as an interpretive framework.[255] To my understanding, the application of the study to the 'Social Networks' is an analysis model that entails a review that comes from the field of economic and social history, of the theoretical frame of the complex networks whose consideration

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255   Eric Van Young, 'Social Networks: A Final Comment', Nikolaus Böttcher, Bernd Hausberger y Antonio Ibarra (coords.), *Redes y negocios globales en el mundo ibérico, siglos XVI-XVIII*, (México: Iberoamericana, Vervuert, El Colegio de México, 2011), pp. 290-307.

raise the possibility of analysing the behaviour of systems made up of multiple interacting elements in a more global fashion and in which human actions have great importance. In short, the force of cooperation, communication, and human skills, as described by William and J. R. McNeill.[256] The analysis framework of complex systems has recently come under study with the aim of applying it to interdisciplinary research and new theoretical contributions using the theoretical and epistemological approach are being offered.[257] The nature of an expanding Atlantic world constantly demands more studies which take into account the interaction between elements which have given rise to new phenomena derived from the very interchange of products, people, and information between various regions linked during the centuries of what is known as the first Global Age. The vision of this world (during the centuries of the most-accelerated expansion which humanity has ever known) as a true complex system is particularly enriched by the idea of stability in non-linear systems.[258] As far as its application to Social Science is concerned, until now some of the most innovative results have come about from the perspective of regional economic analysis and its spatial modelling.[259] 'Spatial trade modelling' is a growing area of research that offers us historians the possibility of representing models of spatial economic systems where the most important

256   J. R. McNeill & William McNeill, *Las redes humanas. Una historia global del mundo*, (Barcelona, Crítica, 2004), Introducción, pág. 6.
257   Rolando García, *Sistemas complejos, conceptos, método y fundamentación epistemológica de la investigación interdisciplinaria*, (Gedisa, 2007).
258   Ricardo V. Solé, Susana C. Manrubia, *Orden y Caos en sistemas complejos. Aplicaciones*. (Barcelona, Ediciones UPC, 2001), pp. 52-61.
259   G.J.D. Hewings, Michael Sonis & D. Boyce (eds.) T*rade, Networks and Hierarchies. Modelling Regional and Interregional Economics*, Springer Verlag Berlín, Heidelberg New York, 2002. Cf. Introducción, pp. 1-11. Frank Schweitser et al. 'Economic Networks: The New Challenges', *Science*, 325, (2009), pp. 422-425.

questions for the commercial logistics of a specific historic period can be visualised, such as the location of the most geostrategic port cities, the possibilities of distribution of resources and goods, people, and information, and all this through specific network establishments. The commercial expansion of the Seventeenth and Eighteenth Centuries has offered different connected scenarios for historians who are specialists in this subject.[260] From Braudel to Wallerstein (with his sociology-based theory of the world economy) this vision has recently been enriched by the contributions of André Gunder Frank.[261] This framework is innovative because it proposes the review of the knowledge already acquired in the study of the different models of colonial expansions and the system or systems generated by them, putting greater emphasis on the connections rather than on the empires, as Fréderique Langue noted in an interesting review.[262] In reality, it is a framework that could mean a transition from Atlanticism to Global History and which is above all characterised by the return to the 'spatial turn'.[263]

From the point of view of the areas of economic interaction and the cooperation of merchants in the Hispanic world, the existing historiography on this subject–which is particularly dense in the Spanish language (little known in the English-speaking world

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260   Ana Crespo Solana, 'Geoestrategy of a System? Merchant Societies and Exchange Networks as Connection Centres in the Spanish Atlantic Trade in the First Global Age', Mukherjee, Rila (eds.) *Networks in the First Global Age: 1400-1800,* (Delhi, Primus book, 2011), pp 11-35.

261   Andre Gunder Frank, *ReOrient: Global Economy in the Asian Age*, (Berkeley Los Angeles, University of California Press, 1998). Unas revisiones de la historia Atlántica en: Michel Morineau, 'Le Systeme atlantique au péril de l'histoire', *Jahrbuch für Geschichte Lateinamerikas*, 43, 2006, pp. 301-316.

262   Fréderique Langue, 'El espacio Atlántico: conexiones imperiales, revoluciones y comunidades mercantiles', reseña en *Nuevos Mundos, Mundos Nuevos*, 2010, online.

263   Pieper, Renate y Peer Schmidt (eds.). *Latin America and the Atlantic World. El mundo atlántico y América Latina (1500-1850). Essays in honor of Horst Pietschmann.* (Köln/Weimar/Wien: Böhlau Verlag, 2005), Introduction, pp. 9-17, p. 17.

and sometimes even completely ignored)–is fundamental in order to define the Atlantic commercial system as a 'social environment' which has a clear systemic nature, derived from the different models of European imperialist expansion but which underlies the analysis of other phenomena that have arisen from the very needs of the exchange led by agents on the move. The example of Spanish Atlantic commerce is a paradigm of network interactions, which would never have worked without their operation. Precisely, the Historiography on Spanish colonial trade stresses the essential role played by non-Hispanic mercantile networks in the economic expansion in the Atlantic. Within the Iberian Peninsula proper, colonies of Anglo-Irish, French, Flemish, and Dutch and of other nationalities maintained a prosperous trade from the main urban nuclei. Late in the second half of the Seventeenth Century and throughout the Enlightened Eighteenth Century, the old enemies of the Hispanic Monarchy had developed certain sophisticated operations within the framework of trade between Spain and America, from within the very heart of the state monopoly, first Sevilla and Cádiz from the second decades of the Seventeenth Century and overall since 1717[264].

The first step to explain the working of this system has a marked sociological and historical theoretical aspect and refers to the description of the mercantile societies and the functionality of the commercial agents spread across the diverse port cities connected to the European commercial expansion and tied to the businesses around the Spanish Carrera de Indias. It was common, given the socio-cultural characteristics of modern Europe, for these

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[264]   Crespo Solana, 'Geostrategy', pp. 11-35.

agents as a general rule, to almost always be part of consulates or what are called 'merchant nations'. They were in any event mercantile communities and describing them in general, and specifically in the case of each nation, leads to a methodological shift toward types of comparative analyses for which there are already established criteria based on sociological, historical, economical, and anthropological conceptual problems.[265] The role which the colonies of merchants played both on a local level and in the connection of port cities on different commercial scales is fundamental in order to understand the European expansion in the centuries of the Modern Age. In the specific case of the Spanish Monarchy's trade, these communities operated as agents that promoted interaction on many levels and can be described as specialized micro-societies around the emerging world of trade and international finance and in many cases, self-defined as 'nations'.[266] The cities where these colonies of cosmopolitan merchants and people of diverse geographic origins were located were converted into a social laboratory which experienced an important degree of interculturality, exchange of information, biological inbreeding and symbiosis but also religious and political conflicts, new forms of social integration and adaptation due to the interculturality itself and the new economic opportunities. From this context the explanation of the funcionality of agents, communities and networks, on their three respective levels, is made possible using two principal analysis frameworks which are used complementarily. One of them is the relational analysis within one group with dif-

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265   Ana Crespo Solana, 'Introducción' *Comunidades Transnacionales*. pp. 9 and next.
266   Crespo Solana, *Comunidades transnacionales*, p. 61.

ferent types of links between them, also complemented by a qualitative analysis, studying the links between the agents and the reasons they had for the exchange, collaboration, or conflict. This method of analysis has produced important results in the study of social groups of the Modern Era.[267] Secondly, and this is still in an experimental phase, there is the reconstruction and analysis of networks, applying new technologies derived from the use of Geographic Information Systems (GIS). Here, the network is not just a metaphor for a series of complex social relationships but rather serves to visualize and represent these relationships with the help of new tools that are being implemented. The merchant network connects with the abstract definition of 'Networks' which is conceptualised as 'mongrel hybrids, located somewhere in the obscure zone between the alleged ideal types or markets and hierarchies'[268]; but also with the idea of social connection where elements of reciprocity, collaboration, altruism, competition or conflict and even betrayal prevail, which characterise to a great extent the social environments where new forms of behaviour emerge under the cover of new challenges posed by social, economic, or political media. As something fundamentally complementary to this first sense, the networks interrelate through economic systems run by or perhaps also defined as 'information systems', which started to be structured from the very beginning of European expansion, at the end of the Fifteenth Century, or even before.[269]

267   José María Imizcoz Beunza, 'Las redes sociales de las elites. Conceptos, fuentes y aplicaciones', Enrique Soria Mesa, J. Jesús Bravo Caro y J. Miguel Delgado Barrado (eds.) *Las elites en la época moderna: La Monarquía Española, Vol. 1: Nuevas Perspectivas*, (Córdoba, Universidad de Córdoba, 2009), pp. 77-111.
268   Gernot Grabher, 'Trading routes, bypasses, and risky intersections: zapping the travels of 'networks' between economic sociology and economic geography', *Progress in Human Geography*, 30, 2 (2006), pp. 163-189.
269   Montserrat Cachero Vinuesa, 'Redes mercantiles en los inicios del comercio atlántico. Sevilla

The study of the functionality of trade networks is decidedly a subject of research that is also fundamental to the application of this methodology, which will complement the theoretical definitions of its make up and operation, as Jonathan Israel has suggested in the case of the Jewish communities of the Caribbean, classifying them as a 'multi-functional economic Framework'.[270] Other studies of the Jewish networks have described these activities as being wrapped up in a varied economic enterprise which combines rural and urban life, something that was typical in the West Indies, dedicated to both shipping activities and finance as well as farming. Moreover, the cases of the Sephardic Jews and other communities, such as the Dutch, the English or the Irish, have already provided results in studies of the Atlantic connections beyond the limited enclaves of these colonies and offer large quantities of data about shipping and commerce.[271]

With the purpose of analyzing the interactions between agents and networks in what has been called the 'Spanish Atlantic system', a broad database of the interconnections that were created in this oceanic area between 1680 and 1778 is being put together, taking into account considerable data on general European commerce, connected directly or indirectly with the 'Spanish System', since in this way the different phenomena relating to the

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entre Europa y América, 1520-1525', Böttcher, Hausberger & Ibarra (coords.), *Redes y negocios globales*, pp. 11-25.

270   J.I. Israel, The Jews of Curaçao, New Amsterdam and the Guyanas: a Caribbean and trans-Atlantic network (1648-1740)', Israel, *Diasporas within a Diaspora: Jews, crypto-Jews and the world maritime empires (1540-1740)*, (Leiden, Brill, 2002), pp. 511-532.

271   Catia Antunes, *Lisboa e Amesterdâo, 1640-1705. Um caso de Globalizaçao na História Moderna*, (Lisboa, Livros Horizontes, 2009); David Hancock, 'The Trouble with Networks: Managing the Scot's Early-Modern Madeira Trade', *Business History Review*, 79 (2005), pp. 467-491; Ana Crespo Solana, 'Dutch Mercantile Networks and the trade with the Hispanic Port Cities in the Atlantic (1648-1778)', Böttcher, Hausberger & Ibarra (coords.), *Redes y negocios globales*, pp. 127-142; *El comercio marítimo entre Cádiz y Amsterdam*, 1717-1778, (Madrid, Serie Estudios de Historia Económica,Madrid, Banco de España, 2000).

Atlantic exchanges can be analyzed and the characteristics and effects of Spanish expansion in its context can be studied.[272] Since 1492 Spain played a decisive role in the stages of the expansion. This 'Spanish Atlantic system' and its colonial trade with America is called the Carrera de las Indias and has, from the outset, certain institutional and socio-political features that somehow determined the remaining European 'expansions'. In fact, the term Carrera de las Indias referred to maritime activity between the Iberian Peninsula and the American colonies as well as every business and other endeavours related to that activity. When a trader engaged in American trade by loading his merchandise onto the fleets and galleons, it was said he was involved in the Carrera de las Indias. After all, this term defined a historical category that entailed the development of a definitive way of life, which was strongly linked or even subjected to, the evolution of a specific, but not limited, mercantile-geographical system, for this system was connected to other trading areas that did not belong to the Spanish empire but were intrinsically linked to it.[273]

The 'Crespo DynCoopNet Data Collections' database contains several queries about actions, agents, cooperation, fleets and ships. All data have identifiers that relate tables. It has 21 full forms that give information on cooperation among agents while identifying partners. Lists with goods and ships are included. A table named 'COOPERATIONS' is also defined, in which all forms of commercial relationships – business, Company, Society, etc. -are represented which take place between agents. This again is new as the study is

not limited to a specific type of commercial operation but has been extended to all types of goods transactions in which two or more agents are involved, be it legal or illegal, be the goods slaves or metals. The objective is to identify all types of commercial networks. In fact, as agents we have people, Societies, Companies, Institutions, etc. There is also a table named 'ACTIONS' where all activities or actions are entered, such as money lending, job commissioning, etc., that occurred within cooperation and were quoted by the sourced used. This table is related to another, very important one – 'SHIPS'. Many of the remaining tables in the initial Access® database store typologies - places, professions, etc. Having chosen the previously described tables as primary (Agents, Cooperation, Actions and Ships) allows us to analyze the various commercial, professional and interpersonal relationships between the various agents, laying the emphasis on their geographic location, chronologic moment and degree of kinship; in short, the cooperation networks they built. (e.g. the importance of Nicholas Magens as a merchant, or that of the Roo or the Amsick families, whose range of action could spread from Alicante to Elche in Spain or from Cadiz to Manila via Mexico. A very important aspect is the data's temporal component. In most cases two fields have been set up for the date value – a date-format one and a text one for when the source does not provide a precise date or the details are inconclusive. We face the same issue with regards to the spatial component – two fields have been set up, one stores the precise name of the spot and another for additional information (e.g. temporary residency) or when the current name of the place is unknown and only the old one is quoted. However, in this first database the places' geographic coordinates –latitude and

longitude - were never input. In relation to this component, a new, differentiating, feature of this project is its geographical scope. Although based on a previous scope, the Atlantic, when sources were investigated, specially those on trips and family networks, the scope widened to encompass the Mediterranean Sea, the Pacific and even the Indian Ocean – the latter is specially relevant when studying the pirates' actions. That is to say, despite having started from a pre-determined spatial range, we have not relinquished the rest of the areas. Thus it is highlighted the importance of the cooperation networks that existed in the period studied and the already existing process of globalization. On all tables the fields NOTES and SOURCES have been added so that every record has attached its own remarks and source quoted. Even on the tables for typologies fields have been added for remarks and definitions for those terms that are disused, obsolete or unknown, in an attempt to add clarity when doubts arise.

The material compiled has been limited to a time frame coinciding with a paradoxical age of lengthy revolution, characterised by continual crises and states of war due to colonial competition and maritime hegemony and in which diverse factors combined that encouraged integration and inequality among the areas of production and the markets. The historical context led to macroeconomic alterations between the Sixteenth and Eighteenth Centuries, producing an increase in demand, greater availability of capital, demographic growth, improvements in agricultural exploitation, an increase of manufacturing production in some regions of Europe and other developments which resulted in changes in the lifestyle of the populations as well as in the

emergence of new social groups, above all in cities.[274] Spanish colonial trade during this period of time was strongly interrelated with what has been called the Atlantic system, defined as the area of interaction.[275] In reality, all the imperial colonies with a mercantile trade base are articulated around networks of complex, personal and non-linear relationships. To a large degree the debates as to whether there were various systems related to the socio-cultural, economic and political characteristics of each expansion model, or just one system in which the processes of each one interacted always tied to and never isolated from the rest, are closely related to a generalized ignorance of the general theory of systems and the abstract definitions of the meanings 'system' and 'model' as they have been used by the Historiography of the Atlantic World in recent years. In reality, a system is a set of organized parts or elements and can form part of another larger set, while the term model refers to an archetype which can be reproduced or not. From this perspective, the Atlantic system is the whole made up of diverse parts that interact, or diverse conflicting models although they sometimes have a lot in common.[276]

One of the factors which gives coherence to a commercial system is the connection of multiple agents in a network, for which the data provided by the commercial endeavours in the ports by

274   Immanuel Wallerstein, *El moderno sistema mundial II. El mercantilismo y la consolidación de la economía-mundo europea*, 1600-1750, (Madrid, Ed. Siglo XXI, 1984), pp. 9-14. Francisco Comín, Mauro Hernández y Enrique Llopis, eds. *Historia Económica Mundial, siglos X-XX*, (Barcelona, Ed. Crítica, 2005), pp. 67-154.
275   Bernard Bailyn, *Atlantic History. Concepts and Contours*, Cambridge – London, Harvard University Press, 2005; Nicholas Canny, 'Atlantic History and Global History', en Pieper y Schmidt (eds.). *Latin America and the Atlantic* World, pp. 25-35.
276   Santiago Ramírez, *Teoría General de Sistemas de Ludwig von Bertalanffy*, México, Universidad Autónoma, 1999; Lars Skyttner, *General Systems Theory. Problems, Perspectives, Practice*, (World Scientific Publishing, Co. Pte. Ltd, 2005).

agents and communities form a raw material for their integration
in a process of representation and visualisation. But, in reality, the
research around the functionality of communities in mercantile
societies and networks could well represent a fundamental
chapter of what could be a global history formed by a number of
interwoven regional studies where a global vision would mean
a study based on a regional economy or an unit of analysis, that
is, the economy of the various interrelated spaces in Europe with
diverging Atlantic areas: 'an interlocking network of trades shaped
by public and private interests'.[277] The information collected in this
database also complements two other databases that refer to trade
with Asia and the financial networks of the Spanish Monarchy.[278]
Thanks to a complete team effort, three great data bases have been
created which offer two important points in common: the three are
integrated and focused on the study of agents as cultural, economic,
social, political and financial mediators, between the Sixteenth and
Seventeenth Centuries. These databases define the very geography
of the system and its parts; they are accessible via the Internet, and
are the raw material for the creation of a Geographic Information
System about the networks of mercantile cooperation in what is
called the first Global Age.[279] They aim to offer representative
models that can be visualised of the types of mercantile cooperation
in the mechanisms which articulated the financial networks of the
Spanish Monarchy, the expansion of the Portuguese empire, that
'shadow empire' which Winius[280] defined, the slave trade[281], gender

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277   David Ormrod, *The rise of commercial Empires. England and The Netherlands in the age of Mercantilism, 1650-1770*, (Cambridge University Press, 2003).
278   Vid chapters 7 and 8 of this book.
279   Ut supra, chapter 5.
280   G. D. Winius, 'The 'Shadow Empire' of Goa in the Bay of Bengal'. *Itinerário* 7 (2), 1983, pp. 83-101.
281   Slave Voyages Data Base (vid. Chapter 3 of this book): David Eltis y David Richardson,

and race relationships in Africa and Afro-America, trade in the South Pacific, the relationships of the big European monopoly companies in Asia and the Americas; Spanish trade with the Americas in particular, and European trade of the monopoly companies in global exchange scenarios in general.[282] All these 'social environments' created by the different behaviour models of the European nations in their commercial expansion had a large degree of interaction between themselves. In reality, this context of European expansion in this long phase of modern and colonial history ended in the formation of a single system where different behaviour models took part, which gave rise, effectively, to a scenario where many variables intermingle and must give stability to the system although with different historic bifurcations almost always produced by external phenomena or processes but which have managed to alter or destabilize all the factors and in a model generally characterised by endemic violence as well.[283] This kind of analysis is generally beyond the scope of the databases, so that the visualisation of data in an histo-ric GIS would be methodological, adequate for the integration of the data, the visualisation and the creation of theoretical behaviour models in the historical systems.

The functionality of the merchant community

The use of this database has various goals although it may be open to other possibilities in the future. In the framework of historical analysis, some of these goals relate to the possibility

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Extending the frontiers. Essays on the new Transatlantic slave database, (Yale U. Press, 2008).
282   Explained in Ana Crespo Solana, 'Data Sets on Cooperation', Paper presented at 'TECT final Conference, Budapest, 15-17 September, 2010. Available in: http://www.esf.org/activities/eurocores/running-programmes/tect/events/tect-final-conference.
283   Vid chapter 1 of this book.

of complementing the descriptive model of a mercantile colony, understanding it on two levels: local/individual/collective on the one hand (that is to say, on the level of the local community) and on the other, as being made up of the components of these local communities in their role as agents in the mercantile networks, a nuance which has a clear transnational element from the social and economic point of view. Both approaches involve geographic questions, but this last one has greater scope, recognising the functionality of the networks as connectors of broad areas of cultural and commercial exchange, along with being linked to the analysis of the trade routes.[284] For example, some of the colonies most devoted to Spanish trade with America have characteristics that can be extrapolated for the study of other communities of other nationalities and cultural, political, and religious profiles in different parts of the world that was interconnected during the centuries of colonial expansion. Whilst on some notable occasions, there has been more in depth study on questions of political transcendence or cultural identity, the majority of the unifying criteria of most of the mercantile communities are those which relate to their social and economic characters and their methods of integrating into the different business networks. In the last decade, studies about these communities have been considerably broadened by new perspectives that starting from the local and transnational levels of analysis mentioned above, expand to include a geographic implication, namely that of the commercial circuits with their maritime or land routes. In short, investigations that delve beyond the colony to comparatively analyse the commercial

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284   Crespo Solana, *El comercio marítimo,* pp. 34.

dimension and the scope of the businesses through the maritime routes and port enclaves.[285] Regarding the merchants as economic agents, it is possible to clarify one issue, which is that the whole of Europe took part in the Spanish economic expansion and contributed to the formulation of the model of social and mercantile exchange that resulted. Foreign communities are omnipresent and preponderant from the very start of Spanish trade with the Americas despite some laws decreed against this by the Castilian crown, which are in fact very ambiguous, because they subliminially allowed clandestine participation.[286] In fact, merchants of all nationalities took part in different ways, which necessarily favoured the creation of complex relationships of competition and cooperation.

Documentary and printed sources have been used to create the database, in addition to consulting the entire existing bibliography about Spanish trade with the Americas. What is very clear is the fact that there are some problems with the sources, as there are many gaps in the information which has traditionally made it difficult to define the group that is the subject of the investigation, therefore given our preference for studying the mercantile networks, we have chosen to analise mercantile colonies of different origins since they offer historians the greatest possibilities for studying specific groups, above the hierarchies and social differences marked by the characteristics of European society of the Old Regime. The sources which have been most used to in-

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285   Examples in: María Jesús Arazola Corvera, *Hombres, barcos y comercio de la ruta Cádiz- Buenos Aires (1737-1757)*, (Sevilla, Diputación, 1998); Crespo Solana, *El comercio marítimo*; María Nélida García Fernández, *Comerciando con el enemigo: El tráfico mercantil anglo-español en el siglo XVIII (1700-1765)*, Madrid, CSIC, 2006;

286   Ana Crespo Solana, 'Legal Strategies and Smuggling Mechanisms in the Trade with the Hispanic Caribbean by Foreign Merchants in Cadiz: The Dutch and Flemish Case, 1680-1750', *Jahrbuch für Geschichte Lateinamerikas*, 47, 2010, pp. 181-212.

vestigate the role of the agents are the notarial document archives, which have enabled the form of European trade of the Old Regime to be profiled, its social behaviour, its types of activities, etc. An important methodological question is the complementing of notarial and private sources consulted in different European cities. In short, when a mercantile colony is studied, one must chose sources in the cities of departure and settlement of the merchants, just as I have indicated in earlier reports works.[287]

Networks and Self-Organising

In an increasingly more global mercantile framework and in some urban centres strongly marked by cosmopolitanism, the self-organising networks of trade formed around the agents themselves. They were the result of some 'societies' joined by economic interests that supported regional growth, and the overcoming of barriers of space and time. It was at the same time the guarantee of sustainability of the ways of life in the societies tied to the global economy. But what were the 'self-organising networks', what do they represent from the historical, sociological, or anthropological point of view and how can one apply this theoretical framework to the study of mercantile networks in the Sixteenth to Eighteenth Centuries. In this project we have used this concept that originally arose in other fields (physics, chemistry, biology, artificial intelligence, and general systems theory) but which has been adopted by sociology in the past two decades[288] to refer to the agents, as actors in the historical

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287   Ana Crespo Solana, *Entre Cádiz y los Países Bajos. Una comunidad mercantil en la ciudad de la Ilustración*, (Cádiz, Cátedra Adolfo de Castro, 2001).
288   J. B. Owens, 'A Multi-national, Multi-disciplinary Study of Trade Networks and the Domains of Iberian Monarchies during the First Global Age, 1400-1800', *Society for Spanish and Portuguese Historical Studies*: Bulletin, 33, 2 (2008).

processes (translated as 'selforganising networks'). Specifically, here a meaning established by specialists in economy and the history of economy is preferred, which defines them as complex and flexible nuclei which form integrated, evolutionary networks in the historical framework corresponding to the centuries of the Modern Era, through traders, producers, communities, and government officials. In the case of the studies about transnational communities, a definition related to the intrinsic functioning of the 'Social Networks' has been used, regarding them as being flexible commercial networks, of international scope and based on family or business relationships.[289]

A number of tools have been used for the analysis of the networks, based on some methodological concepts applied recently to historical-social studies, especially in the case of studies about the family in modern Spain.[290] The UCINET tool was also used, as well as a new application generated by the local interface of the DynCoopNet project. According to these graphical representations, a commercial network spread not just on a local level but also over a broad terrestrial and maritime area, almost always made up by a series of shorter connections with dozens of port cities acting as points of transmission and transfer. The relationships among the networks produced different representations for extension and density and clearly showed the characteristics of a complex network. The diagram (Diagram 1) represents the existing connections among various commercial agents collected in the 'CrespoDynCoopNet Data Collection' database, using the UCINET

289   Margrit Schulte-Beerbühl, 'Mercaderes hamburgueses en Londres y sus redes de comercio internacional (1660-1815)', Crespo Solana, *Comunidades Transnacionales*, pp. 103-116.
290   José María Imizcoz Beunza, 'Familia y redes sociales en la España Moderna', Francisco Javier Lorenzo Pinar (ed.) *La Familia en la Historia*, Universidad de Salamanca, AquiLaFuente, 2009, pp. 135- 186.

software. This network representation is very abstract as it only
shows graphs and nodes without presenting the properties of these
nodes.
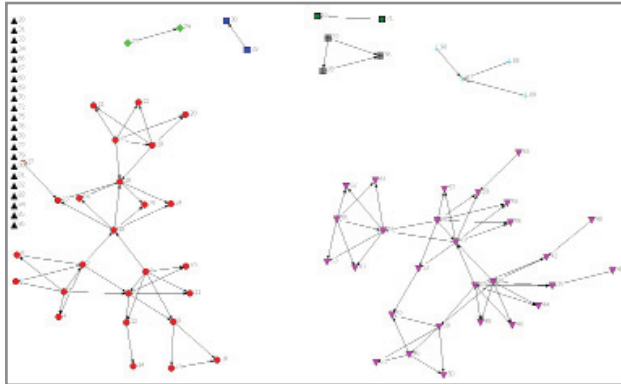
Diagram 1. Commercial Network Model Using the UCINET Tool.

In Diagram 2, a representation of social relationships
according to the network analysis tool included in the 'DynCoopNet
Data provider' has been established, for now only operative on the
local level.[291] The advantage of this software developed by Roberto
Maestre Martínez is that it entails reflecting the identity of the
agents as well as some of their social and economic attributes or
properties, such as the individual's social status or data about a
specific commercial company or activity at a specific moment in
time. The next step is to include this network representation model
in a GIS with various layers where information about the agents
contained in the database can be included: identity, characteristics,

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291   Vid chapter 5 of this book

trades, social and economic status, activities they carry out, etc. In short, this analysis tool aims to be improved in the future with the goal of reflecting more data in layers relating to social and behavioural attributes of the agents.
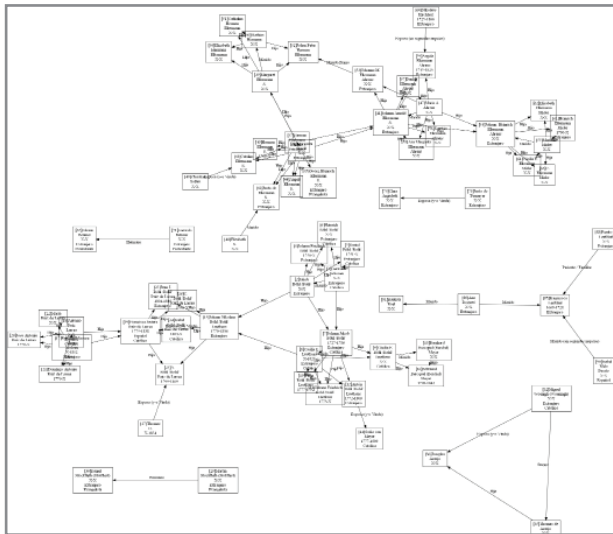
Diagram 2. Example of a Social Network in Cádiz at the end of the Eighteenth Century.

The agents compiled in this representation were citizens of Cádiz, almost all of them related to the mercantile world, between 1770 and 1843. They are of various nationalities, including Spanish. They include several women (belonging to the merchant clan of German origin, surname Ellerman, whose family tree as well as their commercial activities have been studied by Klaus

Weber).[292]

Thanks to its representation it is possible to visualise the threads interlaced among the networks and to establish their theoretical typology in relation to the forms of cooperation or conflict. In the Spanish trade with the Americas, a commercial system of protection was imposed that was nonetheless demolished in practice by the information networks and control of production areas and markets undertaken by the British and Dutch from the second half of the Seventeenth Century. This model of Atlantic network seems to oppose the one described by Antoni Picazo for the case of commerce in the Manila region[293]. This map offers a visualisation of the scope reached by the businesses established by various Dutch companies that traded with Cádiz through various Flemish agents and consignees. The resident commercial firms in Amsterdam negotiated through the route that united various ports of the Baltic, Atlantic-European coast, Iberian Peninsular and the Mediterranean, with Cadiz being a key connection for dealing with various American ports.[294]

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292   Klaus Weber, *Deutsche Kaufleute im Atlantikhandel, 1680-1830,* (Munchen: Verlag C. H. 2004), p. 398.
293   Picazo i Muntaner, Antoni Picazo i Muntaner, *Cooperación y colaboración en la primera edad global, 1400-1800. Modelos comerciales mercantilistas en el Indio* (Pacífico, E-book, IdeaIndia.com, 2010), pp. 104-106.
294   Data in: Crespo Solana, *El comercio marítimo*, Fletes Amsterdam-Cádiz, pp. 118-123. The Map has been ellaborated by May Yuan (University of Oklahoma and researcher of DynCoopNet project); Crespo Solana, '¿Redes de dependencia inter-imperial? Aproximaciones teóricas a la funcionalidad de los agentes de comercio en la expansión de las sociedades mercantiles', Igor Pérez Tostado y Enrique García Hernán (eds.) *Irlanda y el Atlántico Ibérico. Movilidad, participantes e intercambio cultural*, (Valencia, Albatros Ediciones, 2010), pp. 35-50.
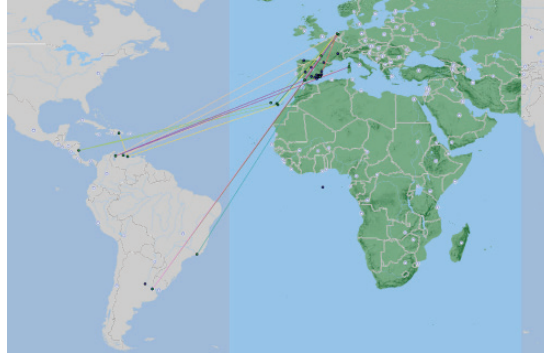
Map: Scope of Business of Commercial Firms Amsterdam (1702-1738).[295]

It is probable that in the future, the graphic and spatial-temporal representation of the networks in their historic evolution will make it possible to establish whether the work carried out within the network enabled the commercial practices to spread rapidly, whether as a result of them cultural diversity was reduced, whether they contributed to promoting more specialised production and division of work, the encouragement of economic diversity or certain communities becoming more specialised around activities of commerce, finance, or farming, etc. Perhaps they can shed more light on whether the establishment of networks allowed for the exploitation of resources in the most efficient but also more aggressive way with the environment, made societies richer but also more hierarchical, and encouraged social inequality and ethnic and religious distrust.[296]

When analysing the spatial organization of the commercial networks around the activities of EuroAmerican trade, these

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295   Map made by Prof. May Yuan, University of Oklahoma, USA.
296   McNeill & McNeill, *Las redes,* pp. 134-278.

networks can be understood as informal mechanisms todetermine information in markets about products and routes. The very way in which the 'merchant nations' were made up encouraged the spreading of a network of mutualism and trust based on family ties but above all on the reputation of some individuals in the colony that was held together by a series of contacts who provided them with information. Partners and informants formed the basic central nodes in the network of a particular merchant but in this case, they could vary according to place, a phenomenon that is also a characteristic of complex systems. This variation does not depend so much on the location as on the collective identity of the colony. For example, in the Cádiz of the Eighteenth Century, it was common for the most established merchants of a mercantile colony to organise their network of members according to this criterion. The Flemish merchants served as a link for contacts among other agents, in the main transients, just as I have shown in describing how the Flemish traders who revealed their oldest tradition to Spanish society used the social and institutional support of a series of corporate bodies (among them the stewardship of the country or the Brotherhood of Saint Andrew) to consolidate their contacts with the new waves of immigrant merchants, many of them originally from the Netherlands in the north, who supplied them with capital and merchandise to continue developing their commercial activities.[297] The same thing happened, for example, in the case of Basque and Navarran traders.[298]

Another example of the phenomena that can be seen with

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[297]   Crespo Solana, Entre Cádiz, pp. 189 y ss.

[298]   Victoria E. Martínez del Cerro González, *Una comunidad de comerciantes navarros y vascos en Cádiz (Segunda mitad del siglo XVIII),* (Sevilla, Consejo Económico y Social de Andalucía, 2006), pp. 219 y ss.

the collection of different layers of information in the representation of networks refers to a subject still worthy of future research, that being the emergence of new ways and behaviours, and their similarities and disparities in social, cultural, and ethnic contexts. In the case of the commercial and financial networks of the Spanish Monarchy in its Atlantic-American expansion, these were generating various superimposed processes of migration, trade, mission work, technology transfer, biological exchange and military conquests, for which these networks were the primary nodules for the establishment of channels where certain interactions relating to the most complex forms of collaboration took place.

Cooperation and forms of trade

A representation of the mercantile networks visually demonstrates that the Atlantic world of the first Global Era was a small world. It was a case of mathematical connection in a complex system according to the model proposed in the formula of Watz and Strogartz, presenting the agents' or entities' (in said network representation) multiple common connections within the network as well as common ancestors.[299] In Diagram 3 the great density reached, for example, by the superposition of multiple merchant networks that operated between various connected port cities in the Atlantic economy is shown.

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299   Ricard Solé, *Redes Complejas. Del genoma a Internet*. (Barcelona, Tusquets editores, 2009), pp. 44-46.
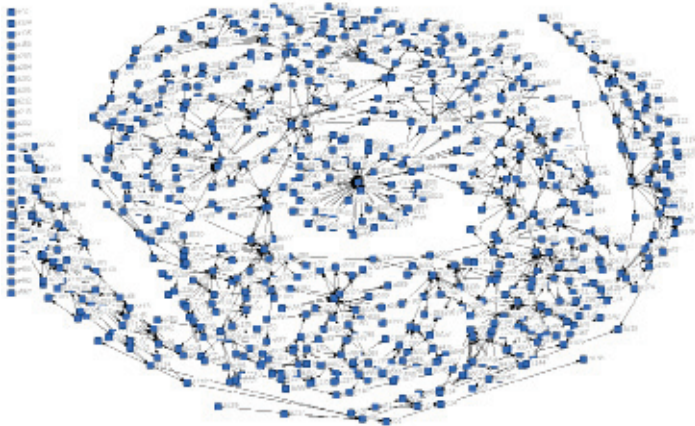
Diagram 3. Example of Density Reached by the Merchant Networks
(Eighteenth Century).

This representation is multidimensional which makes it difficult to visualise unless one uses the GIS. It has data regarding the activities carried out by a large sample of commercial firms, differentiating between agents and companies, considering these as latent forms of cooperation among economic parties. Therefore the data relating to Agents comprise the main basis for the creation of the database's conceptual model. The main structure of this initial database is built around a table 'PruebaAgentes' in which all biographic data related to the individual agents are entered taking into account the various 'worlds' each agent belongs to – social, economic... An individual study and classification has been carried out for each agent; then an attempt has been made to

understand the collectivity as the sum total of all these individuals since all of these are related, as can be observed in the database. In relation to the agents, what is new about this initial database is that the investigation is not limited to agents who are merchants by profession. Instead, any relevant data has been collected related to any agent that takes part in cooperation: representatives, corsairs and pirates, capitalist partners, agents, consignees, etc. All of the latter are agents taking part in cooperation and are part of a global network of trade, smuggling, looting or any other type of cooperation or commercial operation.[300] In sum, a total of 19,007 commercial agents with their respective data, place of origin, years during which, according to the documentation, they are in Cádiz, whether they are registered in the Consulate or not, religion, date of birth or death, etc. have been collected. In many cases, the data are incomplete although some are capable of being broadened and improved. Documentary and bibliographic sources are noted, where more information about the agents can be obtained.

The data about the agents offers information about different ways of trading that help to describe a typology of cooperation just as it is reflected in the documentation used. In general terms, the establishment and ensuing expansion of a specific network is related to what is the main form of commercial activity, based on the transportation of products through different means. To this end, the merchants usually associate themselves, organizing societies, mercantile companies, individual or monopoly, or 'business firms' in the form of an informal agreement between two, three or more individuals with the goal of organizing various types of business

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300   Vid artículo: 'Modelling and implementation of a spatio-temporal historic GIS'.

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around a commercial trip, such as the example of the business Valentín Pérez de Dunilaque carries out in Cádiz.[301] Some of the forms of commercial cooperation that are evidenced in the database refer to the establishment by verbal contract of a business company, something that was perhaps the done thing and a reason why it is so difficult to find deeds of trading companies in the Eighteenth Century. In this framework, many forms of cooperation arise from the very structure of foreign and Spanish colonial trade in the Sixth to Eighth Centuries, based on the monopoly which in turn involved the emergence of many symbiotic forms of mercantile behaviour under the protection of the often ambiguous Spanish laws, especially in relation to the participation of foreigners in the Carrera de Indias.[302] This meant that merchants had to come to agreements based on reciprocity and trust. Nevertheless the Cadiz trading area was also a frontier prone to cooperation, collaboration (creating understanding between various agents with the aim of learning from one another) and conspiracy. Conspiracy is also a form of cooperation, according to the glossary created by Matthew Ciolek.[303] This encouraged competition within the same networks and, in turn, the increase of consumption (like that seen in some economic centres) gave rise to the growth of the number of agents dedicated to brokering the distribution of those products, both within as well as outside of the city (on regional or international levels). In many parts, they were the ones who did the most to encourage the increase in demand for many products. They also influenced the creation of

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301   Ana Crespo Solana, *Mercaderes Atlánticos. Redes del comercio flamenco y holandés entre Europa y el Caribe*, (Córdoba, Universidad de Córdoba, Caja Sur, 2009), p. 27.
302   Crespo Solana, 'Dutch Mercantile Networks', p. 117.
303   Matthew T. Ciolek, (ed.) *Self-organizing Cooperative Networks: a glossary of interlinked theoretical concepts*, Canberra: www.ciolek.com.

institutions, financial instruments or mercantile techniques. In this situation and in the specific case of the Andalusian cities of Seville and Cádiz, the political and institutional framework that occurred in that chronological framework was also important in the success or failure of some of these forms of mercantile cooperation. Some of the activities that this internal machinery most needed were loans, collection of assets, appointment of commercial representatives aboard the ships on which the merchandise travelled, etc. These forms of trading became more complex because of almost non-existent bilateral trading, in the Eighteenth Century, as the system of commission-based trading entailed different scales of business that took place during the course of the long commercial voyages made by the ships. Thus, from the local level of the mercantile colonies' businesses, the contacts between members increasingly involved a multilateral network in a common trade of interest to all the nations but which were, paradoxically in turn, great competitors among themselves on an institutional, state or monopoly company level. As has been indicated before, the ship crews who took part in the Atlantic trading were also a clear reflection of this multilaterality for they were almost always made up of individuals of different nationalities, and even different races and religions.[304]

In general terms, the agent networks revolved around different economic interests that involved different types of businesses within a single commercial circuit. Thus, one could say that a commercial voyage could come to be represented with a certain granularity, depending on the quantity of available

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304   Ramón Aizpurua Aguirre, 'El corso de la Compañía Guipuzcoana: los casos de la lancha San Fernando y de la balandra Nuestra Señora de Aránzazu', *Itsas Memorias. Revista de Estudios Marítimos del País Vasco*, 5, Untzi, (San Sebastián: Untzi, Museo Naval, 2006), pp. 379-392; Picazo i Muntaner, *Cooperación y colaboración*, pp. 130 y ss.

information. This can be seen when the steps or spatial-temporal phases of a specific business are analysed, generally undertaken over the course of various journeys made by a ship, which in the data base we have called 'spectre' and which in the data model is included in a table.[305]

A comparative study of the cooperation can be made if we analyse mercantile behaviours in different economic systems or subsystems. In many of these cases, merchants who wish to get into a specific region are hindered, such as in the case of Spanish merchants in the Seventeenth Century, as demonstrated by Antoní Picazo. Nonetheless, there are clear examples of collaboration among the great trading companies themselves, such as the English Indian Company and the Vereeningde Oostindische Compagnie, which were reflected in the implementation of a framework of buying and selling, in which merchants of different nationalities took part.[306] In those cases, two interesting questions resulted: the social agents used the institutions to set legal obstacles against other mercantile groups and the agents who were victims of this opposition always generated mechanisms to overcome these bad patches or the situations that discredited their commercial activity. The cooperation mechanisms also show that the networks were different in scale, both in terms of their scope as well as in the density with which they were intertwined, although little by little they became more and more dense.[307] One of the reasons for the densification of these networks in the case of the representation

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305   *DynCoopNet Spatio-Temporal GIS*, p. 12.
306   Antoní Picazo Muntaner, 'Comercio y colaboración en el mar del Sur: el ejemplo del patache San Buenaventura', en Isidro Dubert y Hortensio Sobrado Correa (ed.) *El mar en los siglos modernos*, 2 tomos, (Santiago de Compostela, 2009), Tomo I. pp. 485-489.
307   McNeill y McNeill, *Las redes*, p. 180.

of data relating to the Spanish Atlantic trade was that most of the business was carried out through the system of trade on a commission basis that was generally founded on trust, sometimes upheld by kinship, or the achievement on the part of a specific businessman, of maintaining the same partners and agents for a long time. In the case of many colonies of foreign merchants who negotiated with the Americas through Cádiz, this was represented through the setting up of branches which included the mercantile businesses of various commercial firms, as has been deduced from the analysis of their insolvency proceedings. The setting up of branches was a form of transnational business cooperation that could not take place without the trust generated by the social integration of individuals on a local level. Nonetheless, in these social frameworks, an agent had to rely on enough contacts and relationships so as to locate the most reliable consignees and commercial representatives. This was almost always done thanks to the transfer of social information between the parent commercial firms and the residents abroad from those business companies. Thus, the search for the best contact to set up branches in a specific commercial market was made across a network of informants and reputable friends of the primary agent who was obliged, so to speak, to believe in their travelling members and agents.[308] This framework even produced curious happenings such as the fact that merchants who acted as branches of a commercial company could not marry until the verbal or legal contract made with the principal firm had concluded.[309] The setting up of branches and commission-

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308   Crespo Solana, *El comercio marítimo*, p. 47.
309   Described in a curious document of the company Collingh & Gadeyne, Archivo Histórico Provincial de Cádiz (AHPC), Protocolos notariales, 17/3834, fols. 1102-1104v. Año 1725.

based trade had a mercantile and financial element by which the reputation, tolerance, and solidarity of those who engaged in them were constantly put to the test in their daily activities and correspondence.

In this framework, forms of human behaviour which have been highlighted in sociological studies and in the field of evolutionary biology have taken place, which have determined that the Game Theory is not sufficient to model human society, therefore the studies, especially the economic ones, of the mercantile networks should complement the analysis outline based on the 'Game Theory' with other models developed by other sciences of human behaviour, including the field of History.[310] This framework starts from the hypothesis that 'people value payoffs according to whether they are gains or losses compared to their current status quo position'.[311] The interdisciplinary vision that leads us to contemplate anthropological and social theories to understand the evolution of the behaviour of these merchants is very broad and still lacks theorisation, although perhaps some of the closest contributions are those of Hannah Kokko or of Axelrod and Hamilton.[312] These visions complement the traditional historic studies that have already described many examples of human cooperation and conflict, although from a more teleological perspective.

Apart from a typology of forms of cooperation it is possible to describe a typology of agents. The Historiography of Spanish

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310   Herbert Gintis: *The Bounds of reason. Game Theory and the Unification of the Behavioural Sciences*, (Princenton U. Press, 2009).

311   Explained by Herber Gintis in 'The evolution of private property', Paper presented to *Conference Evolution of Cooperation – Models and Theories – Laxenburg, Viena, Austria,* 15-18 September, 2009.

312   Hannah Kokko, *Modelling for Field Biologist and other interesting people*, (Cambridge University Press, 2007); Axelrod, R. & Hamilton, W.D. 'The evolution of cooperation', *Science*, 211, pp. 1390-1396.

colonial trade has established many of these types generated by the great heterogeneity of these forms of commercial participation mentioned earlier by examples. This participation gave rise to the proliferation of a large number of terms to describe the traders, their socio-professional categories (some of them new since 1492) and the typology of the terms to describe them: merchant, dealer, trader, harvester, etc. In the database we have tried to set out these typologies, highlighting the great variety of jobs and activities related to the term 'trader'. The terms: harvesters, shippers, merchants, outfitters, employees, pirates, masters, officials, and even smuggler also appear[313] but here the use of these terms must be connected with an ontological study of the agents, a task which is necessarily proposed before the introduction of this data in an historic GIS. To compare both methodologies could enable some questions relating to their status and citizenry to be defined, some of which must be studied in an evolutionary way and keeping in mind the differences due to geographic origin, religion, identity, or cultural customs. Thus, there exists a hierarchy among the components of the commercial world depending on economic questions (investments, capital, etc.) and social questions (social origin, references of origin, and arrival at place of settlement, etc.) that must be analysed, keeping in mind the social context in Europe.

The identity of the agents (and their social and professional characteristics) are closely related to the establishment of a hierarchical scale related to the value of solidarities and integration, considering factors of family, religion, common origin, language and interests in a specific kind of business, market, or geographic area.

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313   Antonia Heredia Herrera, *Sevilla y los hombres del comercio (1700-1800)*, (Sevilla, Colección Galaxia, 1989), pp. 52 y ss.

As has been shown in many previous works, kinship was a primary factor for establishing business networks and was a close-knit field when it came to collaboration between partners and friends, intervening at the key moments of decision making, the distribution of 'public property' or the moment of choosing partners. An important question to be kept in mind is that the agents, regardless of their social or economic status, had great mobility, making many journeys by land or sea. Just as Hilario Casado stated, the journeys were very common in medieval and modern society and greatly influenced the creation of new areas of sociability and exchange, of language, of cultural inheritances and the transfer of knowledge. The majority of these journeys were made for economic reasons and this is the basis of the mercantile way of life.[314] The database aims to also collect information about some locations of the traders in a specific historic moment, including data about the commercial voyages and what we have called 'Spectre', referring to all aspects of real life on a ship and all its commercial voyages. Related to this data, we have also included data about the different stops, the loading and unloading of cargo that took place in each stop, the agents who took part in those operations and other transfers that arise over the course of a specific commercial journey. The commercial journeys exemplified forms of cooperation, as each stop involved many agents with the purpose of dispatching or collecting merchandise, but moreover, a ship was a small societyat sea where all kinds of situations that gave rise to collaboration or conflict took place. Regarding the commercial activity itself, on

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314   Hilario Casado Alonso, 'Viajes y negocios. Comercio regional y gran comercio en Castilla a finales de la Edad Media.', José Ignacio de la Iglesia Duarte (coord..) *Viajar en la Edad Media. XIX Semana de Estudios Medievales*, (Nájera, 2008), Actas. pp. 305-334.

some of these journeys one could appreciate on the one hand, the stages that a specific business went through until finishing the circle of investment and the making of profits or achievement of results; and on the other, what behaviours stand out in the agents in the different stops made on these business trips. Like the networks, a specific business circle can be exemplified by establishing a model of graphs and nodes. The following diagram makes a schematic representation of the circle of a specific business following the stops of a particular ship.[315] Sometimes the explanation of a complete business circle is difficult if it is not represented, given their durability in time and space. Here one can see the commercial circle as an understood circuit, according to the definition given by Matthew Ciolek: 'A web of interconnected Communications, transportation and movement routes'. This applies to 'the web of connections between geographical places, whereas the term Networks applies to the realm of connections between individuals and entities'.[316]

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[315]   References in: C. Arauz Mofante, *El contrabando holandés en el Caribe y Golfo de México*, (Caracas, 1984), vol. I, p. 84; Crespo Solana, *El comercio marítimo*, Tabla II: Firmas del comercio de Amsterdam que comerciaban con Cádiz en el siglo XVIII); y W. L Roberts, ``Ralph Carr: A Newcastle Merchant and the American Colonial Trade', *Business History Review*, 42, 1968. Made by Juan Manuel Sánchez- Crespo Camacho.
[316]   Ciolek (ed.) Self-organizing Voice Circuit.

Diagram 1: Journey of the Ship 'El Amable' of Adrian Hope & Cía (year 1744)

It is obvious that for the cartographic representation of these business circles, one must establish a GIS with maps, for the connection of those nodes and circuits to other layers of geographic information.

Database Use and Networks of Cooperation between tax farmers in Castile, 1500-1536

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Sebastian de Covarrubias, one of the people better informed about Spanish language during XVIIth, left us this concept of hazienda: "it said of doing, what is to work, because if a person works, does hazienda, and, the person who unmakes and consumes it. It includes wealth ad capital which everyone owns".[317] This sentence is connected with different issues of historical fiscal system. Taxation in all kingdoms of Europe was identified with abilities of financing these wealth and capital that Covarrubias wrote. Covarrubias approach is related with an idea of action and movement, in a way of work, in order to increase incomes. Thus, the concept of hazienda is conceived from a dynamical point of view, not as something static. This idea, we could add, is joined with transferring private wealth to tax system as well as how money

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317   "Se dixo de hazer, que es trabajar, porque el que trabaja haze hazienda, y el que la deshaze y consume. Tómase por el caudal y capital que cada uno tiene". S. de *Covarrubias, Tesoro de la lengua castellana o española*. Edición facYesmil de Martín de Riquer, (Barcelona, 1987) (1ª ed., 1611), vox "hazienda" (p. 679)

could pay the most urgent royal expenses.

This concept of tax system disappeared during the origin of fiscal historiography. So happy lighting in Spain happened just at the end of Ancien Regimen, when both legal recompilation and defining each tax were the main purposes of authors as Covarrubias or Gallardo Fernández.[318] We should not forget that foundations of fiscal system during XIXth century tried to create an image of uniformity and discipline around a central authority dominated by the State. For this reason, a new language was required as a new way of understanding and creating the world, I mean, for defining tax system as a power for the central government.[319] Scholars have taken the projection of first historians about historical tax system without attending the context, creating a representation of fiscal system of XVIth-XVIIth centuries that follows ideas of XIXth[320]. May be for this reason, to study the fiscal system has been considered as a bitter work, linked to questions like how defining each tax. The most traditional historians used to do this kind of studies. It was important on the origins of the fiscal historiography but nowadays

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318   D. Alonso García, "Poder y finanzas en el tránsito a la Modernidad (un apunte historiográfico), *Hispania*, nº 222 (2006), pp. 157-198.
319   An interesting point of view in J. Pro Ruiz, "Des finances royales aux finances publiques: le contribuable et l'administration dans le nouvel ordre fiscal (1833-1852)", "ordre fiscal (1833-1852)" A. Dubet (Coord.), *Les finances royales dans la monarchie espagnole* (XVIe-XIXe *siècles*), (Rennes, 2008), pp. 291-305.
320   Current research tendencies have shifted the orientation. If historian fiscal system was only the study of taxation, now there is a interest for whole fiscal power. J. D. Tracy, "Taxation and State Debt", "State Debt" T. A. Brady et alii. *Handbook of European History. Late Middle Ages, Renaissance and Reformation*, (Leiden- New York, 1994), vol. I, pp. 563-588; R. Bonney, "Introduction", R. Bonney (Ed.): *The rise of fiscal State in Europe c. 1200-1815*, (Oxford, 1999), pp. 1-17 ;For Spanish fiscal historiography, B. Hernández, "Finanzas y hacienda en los territorios de la monarquía hispánica. Revista de una década historiográfica, 1988- 988", "*Tirar con pólvora del rey" o el dinero de todos (Estudios de hacienda y fiscalidad en la España* Moderna. *Cuadernos de Historia Moderna*, nº 21 (1998), pp. 267-326. Cfr. O. Rey Castelao, "Los estudios sobre fiscalidad en la época moderna: fenómeno historiográfico real o aparente?", *Obradoiro de Historia Moderna*, nº 13 (2004), pp. 215-252.

it is possible to find new topics and paths of research.

Nevertheless, tax system during XVIth and XVIIth worked taking advantage of wider social conditions that not only from an economic point of view. The king delegated direct administration along the kingdom in return on loans or bonds. So, taxes were used as debt guarantee. External agents could manage the taxes, as brokers between lenders and tax payers. Of course, they expected improve their own profits, both in an economic and political point of view. It is possible to include cities in this category too, although this paper does not analyze the rol of towns in the fiscal system of Spanish Monarchy.[321] Tax system and financial business was permanent nearly. At this point we found a huge difference with current fiscal systems, where Fiscal State domains administration on the whole. Fiscal collections, on different ways (tax farming, headed tax or fieldad) integrated two aspects different and related. Firstly, as many scholars have pointed out, fiscal collection was a key issue for financing monarchies, cities or the Church. Secondly, fiscal collections give economic, social and political opportunities without it to be considerate corruption because of external agents of crown managed collections with a great liberty. Crown, cities and other authorities used this way of understanding fiscal system to promote people through tax collection. This condition was known and supported as a way to get of participation and integration of financial groups. Attending this factor, taxation included a double goal: to get money in order to support the war, embassies, court

321   There is a long bibliography about this question. See, for example, Ch. J. Jago, "Taxation and Political Culture in Castile, 1590-1640", I. A. A. Thompson, "Castile: Absolutism, Constitutionalism, and Liberty", Ph. T. Hoffman and K. Norberg, *Fiscal Crises, Liberty and Representative Government*, 1450-1789, (Stanford, 1994), pp. 140-181; R. L. Kagan and G. Parker (Eds.), *Spain, Europe and the Atlantic World: Essays in Honor of John H. Elliot*, (Cambridge, 1995), pp. 48-72.

expenses, etc and, on the other hand, personal and institutional
ambitions which could be supported by fiscal system. If taxation
during XIXth and XXth centuries leads redistribution taking
advantage of expenditure –Keynesian policies would be an evident
example-, Spanish Monarchy set off incomes to benefit those groups
that were preferred. So, it usual to find concepts as beneficiar or to
taket taxes a ganancia (o pérdida) included in documents for fiscal
collection, demonstrating that royal incomes depended on people
close to the crown. It is no possible to understand the tax system
without regarding on this context; where external the king and tax
farmers cooperated between themselves.

Groups of financiers for tax collection must be organized.
Fiscal efficiency depended on this factor. Social and political
networks became necessaries for day to day fiscal practice. These
agents not only cooperated with the crown. Networks of clients,
friends and familiars collaborated for gaining positions. This
article analyzes direct cooperation between tax farmer networks
in royal tax system during the first decades of XVIth century.
We need to gain further information about cooperation within
fiscal system in order to approximate to its efficiency and limits.
Scholars have pointed out that collaboration between financial
groups was common. Precisely, we focus on ways and conditions
of collaborations. We must advice that this study attends to direct
collaborations between financial group, not in financial group,
where other kinds of relations, as well important as these direct,
were expected. Studying this first level –that is, when two o more
owner signed a contract for leasing taxes- is basic for appreciate both
the strength and limits of historical tax systems at the beginning of

XVIth century.

Before to examine our results about direct collaboration within Castilian tax system, it is necessary a fast theoretical approach about the concept of cooperation. It is not our purpose to observe all literature from sociology, philosophy or biology about what cooperation means or how cooperation influences in developing human societies. Only we remind that cooperation is one of the most remarkable topics for different sciences and, for instance, it is related on games theory or the study of collective action. Nevertheless it is necessary to explain what concept of cooperation we will follow. Collaboration means a wide concept where two o more people execute at least one action in order to get a goal thought previously. This goal can be individual or collective. From this definition, we are able to find different ways of collaboration depending on their complexity level and integration. The more common goals and planning between agents, deeper is cooperation.[322] In our case, despite that sociology has argued the opposite until last decades; it does not strictly need the presence of institutions or a central organization as a sign of a better / greater collaboration between agents.[323] Rather, as we will see, much collaboration came from the so-called self-sustained groups, ie small structures, informal, selfdirected, with a horizontal hierarchy and with duration limited relatively.[324] During many time, scholars

322   R. Toumela, *Cooperation. A Philosophical Study*, (Dordrecth-Boston-London, 2000).

323   See A. Guiddens, *Sociología*, Madrid, 2007 (5ª. Edi.), pp. 602-615

324   "Self-organization, then, is a fluid process in which informal, temporary teams form spontaneously around issues, whereas self-managed teams are permanent and formally established. Top managers cannot control self-organizing networks; they can only intervene to influence the boundary conditions aroun them.

Extraordinary participants decide who takes part in self-organizing networks and what the boundaries of their activities are, whereas ordinary managers decide who should constitute self-managing teams. Selforganizing networks therefore operate in conflict with and are constrained by the hierarchy, whereas selfmanaginng teams replace the hierarchy. Unequal power, Stacey emphasizes,

have identified vertical organizations as a victorious path of organization. Currently, academic do not suppose that organizations with a more horizontal pattern not to viable. As an example we could say that some of most important Genoese companies of Renaissance work following self-sostained forms.[325] In fact, such structures were dominant during the first decades of the sixteenth century. Contemporaries were aware of this reality. In a book for account officials of Philip II can be read: "They name company, when two or more merchants join money or merchandises, to deal with it"[326] There were larger companies or more complex, simple or composite associations where agents contributed with money, goods, work or time in different proportions.[327] However, as quoted in the last definition, a simple action served as a recognition as a group. And we can imagine how many actions were developed by financial groups, even more without a rigorous control or a central management.

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energizes selforganizing networks through conflict but also operates as a constraint, whereas dispersed powers in selfmanaging teams are supposed to lead to consensus. People on self-organizing networks empower themselves, whereas in self-managing teams the top management empowers people. The self-organizing process is both provoked and constrained by cultural difference, which is at least to some degree unknowable, whereas the self-managing process is based on a strongly and knowably shared culture". R. Lessen, *Management Development Through Cultural Diversity*, (London, 1998), p. 264.

325   D. Alonso García, "Genoveses en la corte. Poder financiero y administración en tiempos de Carlos V", en M. Herrero Sánchez (Ed.), *Génova y la Monarquía Hispánica 1500-1713* (forthcoming) .

326   ["Llaman compañías, quando entre dos, o más mercaderes juntan dineros, o mercadurías para con ello tratar"]. BNE, R/21990. *Manual de contadores en que se pone en suma lo que un contador ha menester saber…,* Madrid, 1589, fol. 160r.

327   J. Heers, *Gênes au XVe Siècle*, París, 1971, pp. 160 y ss. Cfr. B. Caunedo del Potro, "*Comercio y hombres de negocio*s castellanos en tiempos de los Reyes Católicos. Técnicas y aprendizaje", H. Casado and A. García-Baquero (eds.), *Comercio y hombres de negocios en Castilla en tiempos de Isabel la Católica*, (Madrid, 2007), pp. 251-277.

An example of database to study financial networks during with XVIᵗʰ century

Historians as J. P. Murmann has pointed out how relational databases can be useful in humanities studies.[328] In order to study tax farmer cooperation, we have taken advantage of a database designed with access. Figure 1 shows datamodel for relationships:
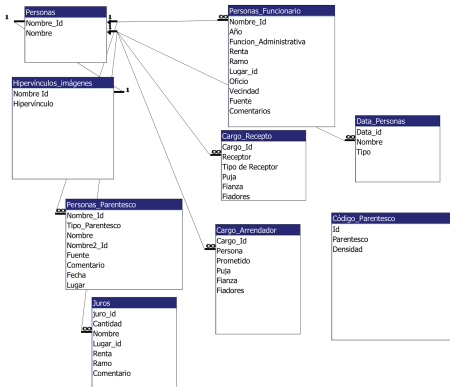
Figure 1: Database model (relationships)

To compose this article, we have used three tables and one consult: 1) People table; 2) a personal information table; 3) A table with links between people and 4) a consult to show the name of people linked previously. In order to include information, we designed a general form with fields from the three tables.

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328   J. P. Murmann, "Constructing Relational Databases to Study Life Histories on Your PC or Mac", *Historical Methods,* vol. 43 (July-September, 3, 2010), pp. 109-123.

Figure 2: Data Entry Forms (detail)

The first table is a key part instead of its only include two field: a key number and a field for people name. As figure 1 shows, the key number has been used to make the relationships. We preferred a single fields to names which includes names and surnames in order to make easier the management of this information. The entry of names has been done including surnames first (for instance, "Vargas, Francisco" for "Francisco de Vargas").

Second table shows personal careers and information. According to "action sociology", where personal careers study is expected from a several points of view,[329] we did not opt for a large

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[329]   L. Boltanski and L. Thévenot, *De la justification. Les économies de la grandeur*, París, 1997. Differences between "action sociology" prosopography has been pointed out in T. Béatouïl, "Critique et pragmatique en sociologie. Quelques príncipes de lectura", *Annales. Histoire, Science Sociales*, nº 25 (2, 1999), pp. 281-317.

table but a concise structure where we could write down the whole information. Database includes a field for dates, another ones for tax system functions, general offices, titles of nobility, citizenship, documentary sources, geographical locations for an event and, finally, a great field for comments. The finishing field would be the most important because we included all kind of information, including transcriptions.

We lost analytical abilities with this structure. However, we addressed a more dynamic structure with a fine adaptation to our sociological model Even more, the fewer field, the less problems for entering historical information within a database, one of the most important epistemological problem in humanities databases.[330] Finally, this election ensures a better conservation of information because we will always display original transcriptions, whose interpretations could change through time.

In this hand, table for personal relationships also includes a short structure. This table is formed by an key identification number related with its correspondent in people table. After that, the table shows a field for the kind of human relation, another one with the name of related person with principal agent, a field for sources and, finally, a large file for comments, designed in the same way that personal information careers. In 2010 we added new field with key identification number of related person and other two fields for places and dates of relationships. More significantly, we defined codes in close list of human relationships (family ties, cooperation or conflict). This table was related with another one with densities. So, with this final design, we can conserve original

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330   J. P. Dedieu, "Un instrumento para la historia social: la base de datos Ozanam", *Cuadernos de Historia Moderna*, nº 24, pp. 11-31.

information –even transcription-, it's possible to manage in a very easy way and, furthermore, codes for relationships can be analyze from a graph theory point of view, with programs as "Gephi".[331] For instance, next figure shows an example of Pedro de Santa Cruz network formed by our database and Gephi:
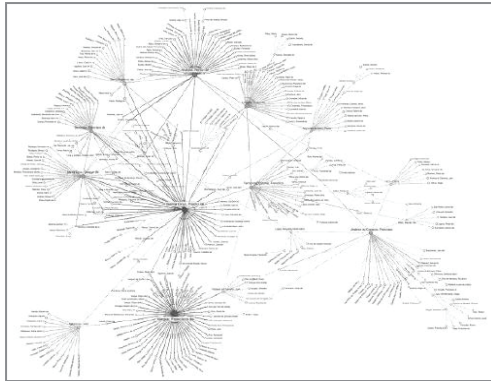
Figure 3: Pedro de Santa Cruz's network. Analysis with Gephi[332]

A companion of the world of tax farming

After this methodological appointment about our database, we would like to start specifying what degree of cooperation existed between tax farmers. Cooperation was regular, known and inherent to the system. In fact, we found 208 of 447 tax farming holdings with two o more owners rather than a single financier. This quantity means a ca. 46.53% of total contracts for tax farming during the three first decades of XVIth century.[333] Thus, almost half

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331   Gephy, free software, is considered one of the most powerful programs for graph analysis (http://gephi.org/)
332   I appreciate Samuel Mesa his help to do this kind of analysis.
333   Source: database

of the agreements were signed with several owners4. However, the level of cooperation is higher than indicated this calculation. Many times, a single legal tax farmer worked for other financiers too.[334] Even more, it is possible to elevate this percentage of cooperation that we find between tax farmers because agents worked with other financiers in different ways not studied in this article, for instance as guarantors.[335] All evidences show that cooperation in the world of tax farming, not only was very spread, but could be considered the soul of the activity. Direct collaboration which we have analyzed had different natures. We have established various types of cooperation under the personal affiliation with categories not mutually exclusives. By *economic* we suppose relations between tax farmers of different cities. When agents presented the same neighborhood, we decided to assign the nature of social, meaning relationship in the group could be more intense than the "simple" purpose to success in the tax collection activity. When we find a family tie, we assign the label of family to this kind of cooperation. Finally, when agents worked for towns councils, aristocrats or State, we have recognized as *political* their relationships with other agents. This last category also includes informal relations.

May be the main surprising evidence in this research is related with family ties. Despite of importance of relatives in the formation of trading companies,[336] most tax farmers were shaped by members of different families. Nevertheless, more stable part-

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334   A regional study for this issue, J. D. González Arce, *La fiscalidad del Señorío de Villena en la Baja Edad Media*, (Albacete, 2002), pp. 356-379.
335   Different examples in J. M. Carretero Zamora, "Los arrendadores de la Hacienda de Castilla a comienzos del siglo XVI", *Studia Historica. Historia Moderna*, nº 21 (1999), pp. 117-152 and the articles include in *Hacienda y fiscalidad en el reino de Granada*. Special Issue of *Chrónica Nova*, nº 31 (2005).
336   Cfr. J. Adams, *The Familial State. Ruling Families and Merchant Capitalism in Early Modern Europe*, (Ithaca, 2005).

nerships existed between members of the same lineage. The most widespread family link within direct collaboration between agents of collecting taxes was established for brothers o when familiar ties were increased by marriages. May be the best example could be the Fuente family. The two brothers, Juan and Diego, were related by marriage to the other part of the company (Juan de la Torre and Alonso de Toledo) as well as other prestigious families of merchants from Toledo.[337] This holding was one of the richer groups during several decades. of taxes, especially about taxes on silk sale.
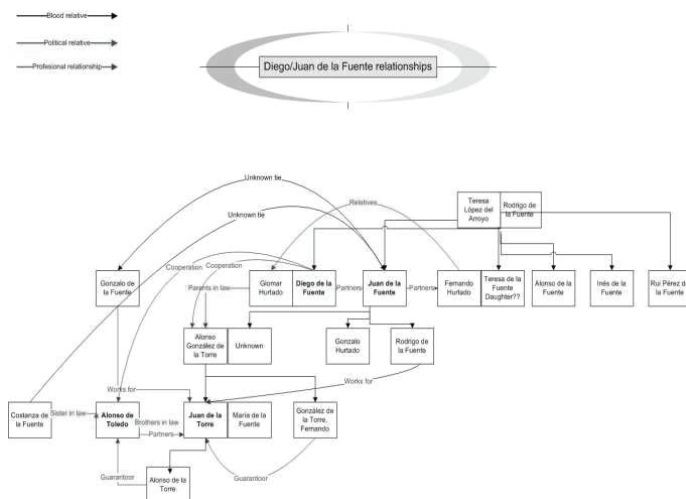
In any case, as we pointed out, the family factor was not the most usual within direct relations between tax farmers. This conclusion, of course, does not invalidate the role of relatives in

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337   L. Martz, *A network of Converso Families in Early Modern Toledo: Assimilating a Minority*, (An Arbor, 2003); D. Alonso García, "Entre Granada y Castilla. La familia Fuente y la Hacienda Real a comienzos de la Edad Moderna", *Investigaciones Históricas*, nº 25 (2005), pp. 11-30.

fiscal agents due to there were hundred and hundred of examples in other kind of cooperation or relations. But not when two o more financiers integrated a company for tax collection. This limited presence of ties family within groups with two o more owners seems quite reasonable because the name of a person was also used to identify to whole lineage. On the other hand, the presence of agents from the same locality became decisive. We find more than 60 examples including relationships between actors coming from the same city. The neighborhood, it could add, grew to be one of the main values to define the collaboration between tax farmers, as we will see after.[338] Finally, political was one of the most extended between agents. It was not strange finding financiers as Gonzalo del Campo or Diego Valderrama who worked very close to Francisco de Vargas, the general treasurer of Castile between 1507 and 1523.[339] Pedro del Alcázar, one of the most remarkable Sevilian merchant, was the father in law of Mariscal de León, royal accountant official.[340] Francisco de los Cobos was linked to Molina family of Úbeda.[341] The son of Nuño de Gumiel, treasurer of Philip I,

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338   About the concept and use of neighborhood within Modern Spain, T. Herzog, *Defining nations: inmigrants and citizens in Early Modern Spain and Spanish America*, (New Haven-London, 2003). Related on merchants..., R. Fagel, "Cornelis Deque, un mercader flamento en la Castilla del siglo XV: un debate sobre el concepto de "vecindad" y "naturaleza" entre mercaderes", H. Casado Alonso (Ed.), *Castilla y Europa: comercio y mercaderes en los siglos XIV, XV y XVI*, (Burgos, 1995), pp. 241-263.

339   C. J. de Carlos Morales, *Carlos V y el crédito de Castilla. El tesorero general Francisco de Vargas y la Hacienda Real entre 1516 y 1524*, (Madrid, 2000); D. Alonso García, *El erario del reino. Fiscalidad en Castilla a principios de la Edad Moderna*, 1504-1525, (Valladolid, 2007).

340   About Pedro del Alcázar as tax farmer, J. M. Carretero Zamora, "Los arrendadores..."; D. Alonso García, "Poder financiero y arrendadores de rentas reales en Castilla a principios de la Edad Moderna", *Cuadernos de Historia Moderna*, 31 (2006), pp. 117-138

341   M. Danvila, *Historia crítica y documentada de las Comunidades de Castilla*, Madrid, 1897-1899, vol. IV, p. 640. Molina family come from Úbeda/Baeza zone, this is, the región de biggest influency of Francisco de los Cobos. About this person, H. Keniston, *Francisco de los Cobos. Secretario de Carlos V,* Madrid, 1980; J. Martinez Millan (dir.), *La Corte de Carlos* V, (Madrid, 2000), vol. III, pp. 87-94; I. A. A. Thompson, "Administración y administradores en el reinado de Carlos V", en F. Martinez GIL, *En torno a las Comunidades de Castilla. Actas del Congreso Internacional "Poder, conflicto y revuelta en la España de Carlos I* , (Cuenca, 2002), pp. 93-107. J. Fernandez Garcia, "Francisco de los Cobos. Aproximación

also participated as tax farmer with agents like Pedro del Alcázar. It is not unusual to find informal ties between tax farmers and king's officers. Such is the case of Juan Alvarez Cisneros, defined as "servant" of Periáñez, the accounting officer of Antonio de Fonseca, one of the most influence person in Castilian tax system.[342] Even a group of tax farmers closely linked to circles of Cardinal Cisneros can be detected, where García Álvarez de Madrid and Esteban de Vargas. Both, significantly, were citizens of Alcalá de Henares.[343] In conclusion, relations with the most influential figures in government finance facilitated access to tax farming. This fact confirms political links were a key issue to keep whole system successfully.[344] Moreover, agents of collection cooperated with brokers or intermediaries within court in order to achieve necessary documentation for executing tax burden. These *brokers*, also defined as "estantes in Corte", should gained trust for financiers and officials of king. In conclusion, the evolution of fiscal institutions cannot be done regardless of developments in the financial world, just as this study about cooperation must look at the institutions.[345]

Many tax farmers also collaborated with local governments. Hence, it is not surprisingly the presence of *regidores, veinticuatros or jurados* among agents of fiscal collections. This element shows

historiográfica a un estudio de la persona", en F. Sanchez-Montes y J. L. Castellano, *Carlos V. Europeísmo y universalidad*, (Madrid, 2001), vol. II, pp. 225-241.

342   AGS, *Escribanía Mayor de Rentas*, leg. 105.

343   García Álvarez de Madrid showed as guarantor to Diego López de Mendoza, Cisneros' secretary. AGS, EMR, leg. 132. Diego López de Mendoza was the most important tax headed receiver during 1506-1507, when Cardinal Cisneros was named regent of kingdom of Castile. D. Alonso García, *El erario...*, pp. 235-236.

344   Ibidem.

345   More information about in D. Alonso García, "Capital privado y fiscalidad regia en Castilla a comienzos de la Edad Moderna", S. Cavachiocci (a cura di), *La fiscalità nell'economia europea. Secc. XIII-XVIII. Atti degla 39 Settimana di Studi*, vol. II, (Prato, 2008), pp. 793-800.

instances of social mobility related to economic or financial activities. May the best example of presence of financiers in Castilian city councils was the Alcázar family. Both Pedro and his son Francisco were well represented in Seville oligarchy, achieving the rol of venticuatros. This family kept an important influence in Seville government during more than one century.[346] But not only in Seville existed a deep relation between local authority and tax farmers. Francisco de Mena and Peter/Gaspar de Santa Cruz worked in Aranda del Duero, a village near of Burgos. All three occupied a office of regidor.[347] Toledo, on the same line, was characterized by a large group of merchants who achieved municipal offices as well. Surnames as San Pedro or Fuente would be a great examples of political collaboration between tax farmers.[348] Even in Madrid it is possible to locate the same condition: the Monzón family, who worked with Toledo's families, also began to be influential in the city as notaries. They will become regidores few decades after.[349]

Demarcations: where tax farmed collaborated

Origins of tax farmers leave us surprising conclusions. First, we ought remember that, in different cases, it is possible to find multiple neighborhoods for the same agent. Financiers had the

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346   R. Pike, *Aristocrats and Traders: Sevillian Society in the Sixteenth Century*, Ithaca-London, 1972; J. Aguado de los Reyes, *Riqueza y sociedad en la Sevilla del siglo XVII, (*Sevilla, 1994); J. Gil, *Los conversos y la Inquisición sevillana*, esp. vol. III, (Sevilla, 2001), pp. 194-205.

347   M. Diago Hernando, "Arrendadores arandinos al servicio de los Reyes Católicos", en *Historia. Instituciones. Documentos*, nº 18 (1991), pp. 71-95.

348   D. Alonso García, *El erario del reino…*

349   Information about this family of Madrid in, M. P. Rábade Obradó, *Orígenes del notariado madrilène: los escribanos públicos en el siglo XV*, (Madrid, 2001); A. Guerrero Mayllo, *El gobierno municipal de Madrid (1560-1606)*, Madrid, 1993; *Familia y vida cotidiana de una élite de poder. Los regidores madrileños en tiempos de Felipe II*, Madrid, 1993; A. Alvar Ezquerra et alii, "Los escribanos del Concejo de Madrid (1561-1598)", *Cuadernos de Historia de España*, vol. 79 (2005), pp. 167-201.

possibility of shifting their neighborhood, or even simultaneously.[350] Several tax farmers used different neighborhoods depending on their own interests. They could were born in one city, to get married on other locality and after, even, move to other part of kingdom. It was allowed to maintain properties on each town. Diego de Alarcón was recognized citizen of Ocaña for his origin and citizen of Úbeda because "has haven and has his wife, house and site in the named city of Vbeda".[351] However, he kept lands, houses and vineyards in Ocaña, the place of origin. Lope de Urueña, one of the most influential tax farmers of this time, was able to te recognized as citizen of Trujillo, Tordesillas and Valladolid in different years. The conclusion is clear: there was an extraordinary mobility between tax farmers, where it is possible to understand this mobility both in a geographically and social-political point of view.

Next table includes neighborhoods of tax farmers of Castile for the period. It would be too tedious to name all the parts of Spain with representatives in these collecting activities. Thus we extract only the main centers of business by number of agents.

CITY	NUMBER OF TAX FARMERS	REGION
Grenada	37	Andalusia
Seville	34	Andalusia
Toledo	27	Center Castile
Madrid	19	Center Castile
Baeza	18	Andalusia
Valladolid	17	North Castile
Almagro	16	Extremadura
Alcala de Henares	14	Castile Center

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350   D. Alonso García, "Poder financiero…"
351   "ha tenido e tyene su muger e casa e asyento en la dicha çibdad de Vbeda". AGS, EMR, leg. 556. This tax farmer appears as citizen of Alcalá de Henares in AGS, EMR, Leg. 551.

Segovia	13	North Castile
Llerena	11	Extremadura
Ubeda	11	Andalusia
Burgos	10	North Castile
Jaen	9	Andalusia
Malaga	9	Andalusia
Medina del Campo	8	North Castile
Aranda del Duero	7	North Castile
Cordova	7	Andalusia

Largest area by number of tax farmers was Andalusia, with 125 cases. This date was logical considering the number of headed taxes was bigger in Castile that not in the south of Spain.[352] There were three main areas of influence around Granada, Seville and Jaén, this last one with a lesser degree of influence. In Castile, on the other hand, we find two great regions of influence: the center of Castile, with 60 agents, whose first city was Toledo, followed by Madrid and Alcala de Henares. North Castile, with fifty five tax farmers, offered Valladolid and Segovia as major centers. Finally, Almagro and Llerena, as areas of military orders, provided a not few number of agents. However we must consider that showed villages in the table gather around 65% of complete list of tax farmers, which demonstrates that agents of collection was quite widespread within whole Castile. The greater number of number of tax farmers does not involves a higher influence. Madrid represented the good example on this sense. In this city lived an interesting number of modest agents who did not achieved preeminent positions within whole tax farmers. Segovia, on the other hand, presented only 13

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352   D. Alonso García, *El erario…*, pp. 24 and following.

agents. However, his influence as financial center was bigger than Madrid due to Francisco Fernández Coronel, may be most influence tax farmer of Castile, who collected taxes over thirty million of maravedíes in 1517.[353]

Analysis of neighborhoods in direct collaboration between tax farmers indicates that most of them came from Andalusia, which reinforces the idea of largest groups lived in this region. Seville and Granada, as well as different locations in their area of influence, remained as centers where more associations were shaped. Emphasize at this point Alcázar family, around which there will be a large group of agents in the area of Seville. And not only Seville; Pedro del Alcázar kept different association with people from Segovia, Aranda del Duero, Gumiel de Izán or Baeza. Their partners maintain direct cooperation with other tradesmen. These one collaborated with others... Therefore, we find more than 60 direct collaborations using a "Erdös- Number" where Pedro del Alcázar would be the beginning. The result from a geographic point of view is a network extended by almost different zones of Castile.[354] Agents of Toledo, Alcalá de Henares and Almagro sought out partners in order to do successful their business with tax system. In any case, as we anticipated, Tax farmers had access to collections over different regions, a fact which comes to realize the complexity and extent of a system that allowed income groups far apart from entering respect to their natural area of influence.

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[353]   J. M. Carretero Zamora, "Los arrendadores…", p. 167.
[354]   D. Alonso García: "El fenómeno del arrendamiento de rentas reales en Castilla en los siglos XVI y XVII: nuevas vías de análisis", *Viator: Medieval and Renaissance Studies,* nº 43 (2012) (forthcoming)

Organizations: how tax farmers collaborated

We approach to a chronological explication of collaboration between 1500 and 1530. Most cooperation behaviors happened during the early years of the century, especially after 1504. During this decade were signed about half of the contracts with companies with two o more partnerships. In the following decade, collaboration remained at acceptable levels. Significantly since 1525 a very noticeable decline in the number of tax farming occurred. In order to explain this decrease, we should attend to Emperor's fiscal policy after Comuneros defeated, just when political conditions shifted. Previously, financiers worked as tax farmers or controlling much of headed taxes like a conditions of their loans. After 1522-1525 tax headed will be developed increasing direct relationships between cities and crown, without so many intermediaries.[355] Thus, tax farmers was so necessaries due to the new role played by cities. The default arrived for the leading agents in the past two decades, as Fernández Coronel Coronel or Pedro de Santa Cruz. Tax farming and cooperation did not died, but were transformed. Less taxes would be collected by this system, specially within alcabalas and tercias. Other duties, on the other hand, maintained a leasing system. Due to the highest rates of collaboration were found in the south, not surprising the presence of several operators in the greatest duties of Andalucia. Sale taxes needed a significant presence of merchant in order to make them successful. Thus, high taxes over silk production in Granada or the Sevilian's *almojarifazgo* –a tax over both import and export of commodities- invited to cooperate. Other

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355   D. Alonso García, *El erario del reino…*

taxes of this zone will be lease as well. However, a general contract was sign between Seville and Ferdinand the Catholic in 1514 for heading much of taxes of this city. Cooperation would continue in these scopes. And this cooperation would be developed between international bankers confirmed as replacement of much Castilian tax farmers.

Tax farming was developing as a collective phenomenon during the first decades of sixteenth century. Financiers used tax farming in order to improve economics profits and to gain political influence. Between entrepreneurs happened business, agreements -or disagreements-, negotiations and discussions. It should be underlined that many cooperation behaviors happened within agents living in separated locations, which, as we have seen, speaks of a high degree of integration throughout the kingdom. To reach cooperation it had to know and to be known, to negotiate with other agents and to manage relationships. This was only feasible within a particular world where agents controlled information about finance or their possible partnership or members of the royal institutions. This how-know was achieved using informal channels where tax farmers and merchants worked.

We would remember that, in a lot of times, taxes were not directly collected by the primary tax farmer but by a secondary financier who had leased it from the first agent directly.[356] This tendency will be increased within changes happened around 1510, when happened a consolidation bigger tax farming. Taxes arrived at secondary market where collaboration between first and secondary agents was basic.[357] In our opinion, cooperation

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356   J. M. Carretero Zamora, "Los arrendadores…".
357   D. Alonso García, *El erario del reino*… pp. 266-270.

between actors from different parts of Kingdom contributed to the economic and social articulation of whole Castilian. With tax farmers, many of them merchants as well, traveling products, news and influences. We could understand a reason why these people reached an important social influence, even further on tax system. As we quoted, Pedro del Alcázar maintain relations with people from Tordesillas, Trujillo, Aranda del Duero and Segovia. He also worked with Genoese merchants. So, we could consider this example as a symbol of tax farming as an activity whose analysis should not be addressed exclusively from an economic point of view.[358] In fact, Pedro del Alcázar was an very remarkable merchant of oil and wine and, taking advantage of this position, bought different houses in Sevile which have been owned previously to Francisco Riberol, a Genoese pioneer in business with Canarias Islands.[359]

An important aspect within merchant or financial collaboration concerns to shapes of organization between two or more agents. As scholars are pointing out during the last decades, internal forms of management in commercial associations represent a key issue within a possible success, especially for incidence in going down transaction costs.[360] In many cases, collaboration in tax collections was related to other businesses. Even in setting up merchant associations is possible to find out interests in taxes collection.[361] We could difference three basic ways of association

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[358]   Cfr. M. Vester, "The Political Autonomy…"

[359]   AGS, EMR, leg. 142. L. de la Rosa Olivera, "Francisco de Riberol y la colonia genovesa en Canarias", *Anuario de Estudios Atlánticos*, nº 18 (1972), pp. 61-198.

[360]   H. Casado Alonso, "Los flujos de información en las redes comerciales castellanas de los siglos XV y XVI", *Investigaciones de Historia ·Economic*, nº 10 (2008), pp. 35-68. About the concept of transaction costs and its influence within tax systems, M. Levi, *Of Role and Revenue,* (Berkely-Los Angeles-London, 1988), pp. 23-38.

[361]   H. Casado Alonso, "Comercio, crédito y finanzas públicas en Castilla en la época de los Reyes Católicos", A. M. Bernal (Coord.), *Dinero, moneda y crédito en la Monarquía Hispánica*, (Madrid, 2000), pp.

within tax farmers. Further than family associations that we have mentioned previously, is possible to figure out a way of associations of long nature, when a same partnership used to be chosen everywhere. These kinds of elections were not too usual. However, they got a large influence for number, variety and quantity of taxes collected. May be the most evident example could be the association between Hernán Suárez de Lara and Pedro Gómez Cabrera. They worked together since 1510 in collecting taxes of North Castile. This association ought to be successful because in 1514 the found other partner: Fernando Gutiérrez, citizen of Placencia. Hernán Suárez de Lara was citizen of Segovia while Pedro Gómez de Cabrera was citizen of Madrid. The three financiers leased taxexs of, Valdeguareña, Tordesillas, Provincia de León, Plasencia, Ciudad Rodrigo, Avila Alcántara between 1514-1522, provided with a high degree of capitalization.

There was another form of collaboration more extended. In general, cooperation within tax farmers was not defined by stability. Even it was not strange to firm different collaborations with several agents. Therefore, general schema of collaboration did not mean hierarchical patterns but particular and horizontal networks. They conducted themselves in a very dynamic or flexible point of view. But they are volatile as well. Each partner involved with his parents and their own people, if any, always attending to shape informal networks. Informal but very effective, I might add. We find, thus, a great world of little relations that formed a whole system, with different points and lines, always keeping that form of self-sustained group that we mentioned previously. These networks constitute a complex system where agents, brokers and subordina-

tes worked. It is not possible understand their relation looking for those individual links, but as a part of a *complex and nonlinear system*.[362] We will take the example of the Alcázar again. The Alcázar family used as agent Juan Alemán systematically in multiple tasks, in aspects as tax system, commercial issues or, even, as procurador in trials.[363] At the same time, Francisco del Alcázar served as guarantor of Alonso Alemán,[364] who, moreover, had been official of Gonzalo del Puerto, also Sevilian, one of the bigger tax farmer of whole kingdom between 1510-1512.[365] Alonso Alemán kept an evident informal relationship with the Alcazar family. Nevertheless, despite of his "Alcázar contact", he also worked for or with others financiers of Seville. A similar pattern is repeated with the Fernández de Sevilla. Gonzalo Fernández de Sevilla joined other merchants in Seville, Francisco Ortiz and Fernando Alcocerbetween 1503 and 1506. A couple of years later we find Pedro Fernandez de Sevilla as agent of Gonzalo del Puerto.[366] Far from being a model company to stable, well ordered and easily recognizable, financial Castilian networks showed a lot of relationships and the ability to serve on different levels. This does not imply the absence of other ways of organization, especially when we speak about merchants from Burgos.[367] However, it prevailed a more horizontal and less

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362   M. I. Sánchez Balmaseda, *Análisis de redes sociales e Historia: una metodología para el estudio de redes clientelares*, (Madrid, Universidad Complutense, 1995), (ph dissertation aviable on http://www.ucm.es/BUCM/tesis/19911996/H/2/AH2011901.pdf). An introduction about complexity systems sciences, A. Sánchez, "Complejidad: Mecánica Estadística y Ciencia no linear", *Boletín de la Sociedad Española de Matemáticas Aplicadas*, nº 34 (2006), pp. 176-189. M. Mitchell, *Complexity. A Guided Tour*, (Oxford-New York, 2009).

363   AGS, EMR,leg. 175; AGI, Justicia, leg. 696, nº 3, R.1. Cfr. C. Mathers, *Relations between Burgos and the Crown*, 1506-1556, An Arbor, Michigan, 1973, p. 241.

364   AGS, EMR, leg. 156.

365   AGS, RGS, 17-11-1510.

366   Ibidem.

367   Cfr. B. Caunedo del Potro, "Comercio y hombres de negocios…"; H. Casado Alonso, "Crecimiento económico y redes de comercialización en la Castilla septentrional (1450-1539)", J. I. Fortea

pyramidal model. In fact, a less pyramidal model can be detected between merchant groups of Sevile, even when they came from Burgos.[368]

Historians have pointed out *fiscal States* in Europe showed important limits of performance.[369] How tax farmers were organized should have influence in whole system. Of course, horizontal and not centralized groups contributed to do confuse information. Despite of efforts made for kings in order to manage all information about fiscal collection,[370] officials only knew the financial solvency of these financial statements based on field research. Tax farmers should present pledges, but they were no enough for doing payments sure. Furthermore, fiscal institutions sent agents to village in order to know if financiers and guarantors were reliable. This agent went to towns, where neighbors were interrogated about possessions, goods or experiences of members of companies. Of course, answering was only valid for members of the same village of financiers instead of companies collaborated with people from other villages or regions of whole kingdom.

Pérez (Ed.): *Imágenes de la diversidad. El mundo urbano en la Corona de Castilla* (s. XVI-XVIII), (Santander, 1997), pp. 283-322.

368   N. Palenzuela Domínguez, "Los mercaderes y hombres de negocios burgaleses en Sevilla en tiempo de Isabel la Católica", *Comercio y hombres de negocio…*, pp. 331-352.

369   Between different titles about, inside a wealth of bibliography regarding this matter, J.B. Collins, *Fiscal limits of absolutism. Direct Taxation in Seventeenth-Century France*, (Berkeley, Los Angeles, London, 1988). G. Muto, "Tra centro e periferia: la gestione della "Hacienda" nell'Italia Spagnola", *Rassegna Storica Salernitana*, nº 5, pp. 51-76. Separata; A. Molho, "The State and Public Finance: A Hipótesis Based on the History of Late Medieval Florence", *The Origins of the State in Italy, 1300-1600. The Journal of Modern History*, vol. 67 (diciembre, 1995), pp. 34-61. For Castilian tax system, furthermore other titles cited, A. Mackay, "Hacienda y sociedad en la Castilla bajomedieval", *Estado, hacienda y sociedad en la Historia de España*, Valladolid, 1989, pp. 47-78; J. Fontana, "Estado y hacienda en el "despotismo ilustrado", en *Idem*, pp. 125-147; B. Yun Casalilla, "Aristocracia, Corona y oligarquías urbanas en Castilla ante el problema fiscal. 1450-1600. (Una reflexión en el largo plazo)", en *La gestión del poder. Corona y economías aristocráticas en Castilla (siglos XVI.-XVIII),* (Madrid, 2002), pp. 73-104 (original publicado en 1991); I. A. A. Thompson, "Castile..."

370   J. M. Carretero Zamora, D. Alonso García, *Hacienda y negocio financiero en tiempos de Isabel la Católica. El libro de Hacienda de 1503*, (Madrid, 2003).

The *Contaduría Mayor de Cuentas* –the institution for revising every tax management in order to avoid corruptions- could only perform their function taking advantage of accounts presented by financiers, so that information were leaked by same people which were investigated. Officials were no innocent. Fiscal institutions ought to make sure the credit. It was essential to maintain contacts with the financial world in order to do tax system successful.[371] It was no necessary to be too strict with agents who maintained an internal solidarity because of networks of collaboration. The king had significant problems to control the system because he depended of this world of cooperation at different levels. But the system worked because the kin maintained access to credit taking advantage of these networks. In fact, tax farmers delayed and cancelled payments during all period without tax system had an effective ability of forcing to obey the contracts.[372] Even more, debts accumulated for tax farmers were renegotiated in new contract with same financiers who did not pay previously, so that taxes could be leased on several occasions without doing payments more secure. The financial system appeared with knitted interest for both financiers and institution, where both depended on both. This model was reached through an intense cooperation between tax farmers, and between tax farmers with officials of institutions. Financiers could be shifted if their credit were not enough for King –this happened after Comuneros revolt, when Castile tax farmers will be replace by international bankers definitively -, but whole system will continue depending on cooperation both between merchants and between agents and royal officials. The funding

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371   See a document about in AGS, DC, leg. 3, fol. 59.
372   D. Alonso García, *El erario del reino...*

possibilities remained linked to the profits of collection. Financiers –or cities- earned money or privileges within different ways while the crown achieved their main goal: money and credit, specially credit, the real purpose of financial efficiency before liberal State.

Conclusion

We could ask ourselves why those forms of internal organization in s*elf-organizing networks* not solved the political and financial crisis of 1520-1525. Comuneros carried on Charles V to a hopeless situation. After 1523, headed taxes –encabezamientos- would be a preferred way of collection instead of tax farming. The answer, obviously, must address to   several elements. First, it is clear that changing political conditions after 1522 strengthen the role of cities in fiscal policy of Charles V. The creation of a *Diputación en Cortes* with extended influence in tax systems is another example of a political system where local oligarchies were more and more important. This overview was completed by the inability of the traditional system of tax farming to face their financial obligations. Institutional transformation, with the creation of as Council of Finance, also depended on political and economical transformations[373].

May be this question can be completed with another way of understanding. If we think the political and economic conditions were not the most favorable from the end of the reign of the Catholic Kings, *self-organized networks* on tax farming did not helped to maintain an acceptable level of working for whole system? It should not be forgotten the serious political crises in Spain was

[373]   Ibidem.

accompanied by remarkable success in the foreign policy: the Italian wars, the campaigns of Melilla, Oran, Mazalquivir and the first steps in America represented a first period of Castilian expansion, after continued for Habsburg dynasty. This first expansion needed credit and financial groups to hold this construction. Genoese bankers did not the biggest creditors yet. Castilian groups, in fact, managed millions and millions of maravedíes each year... despite of political instability. However, political instability and social pressure for tax farmers (much of them were *conversos*) were weaken all system. The civil war of 1520-1522 and furthermore, new political conditions after *Comunidades* would be a too heavy situation to be overcome.

The ways of organization from unstable, informal and non-hierarchical links, where cooperation is expected, did not constitute a lower stage of organization. In fact, in the seventies of the sixteenth century triumph management systems based on "commissions", I mean, servants recruited in different places to perform a determined activity for certain price.[374] Spaniards and especially the Andalusians tax farmers were familiar with a similar ways of organization several decades in advance. To keep a non vertical group is not more or less modern that a traditional company, where a boss seems a god. Any kinds of relationships should not be understood as key of progress or advance, but how they to adapt in contexts. The current economic theory does not support a hierarchical structure of large companies may be more coherent or effective than self-organizing ways, for example, as microcredit system in India demonstrates. In fact, during the "First Global Age" informal ties, families in many cases, were expected

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[374]   H. Casado Alonso, "Crecimiento…"

rather than vertical organizations. These ways of cooperation helped to join economic spaces. Large companies lived and nourished this reality. The Castilian treasury also lived of and with tem... at least for several decades.

Ports, Trade and networks. One example: Trade in Manila. Databases for a Historial GIS.[375]

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Introduction

The study of the commercial networks of the Indian Ocean and the Pacific not only affords us insight to the structural development of modern capitalism and the relations that were established between Europe and the East; it also enables us to delve more deeply into the consequential changes in the commercial system of the Atlantic Ocean[376] and the economic imbalances that arose in the mother countries as a result of market globalisation. Indeed, as Cuebas and Vicente cite, *"...the second law of thermo-*

376   Vid. D. Birminghan, *Trade and Empire in the Atlantic, 1400-1600*, (London: Routledge, 2000); B. Stein and S. Stein, *Silver, Trade, and War: Spain and America in the Making of Early Modern Europe*, (Baltimore: JHU Press, 2000).

dynamics predicts the breakdown of all structures over time. Ordered things will no longer be in order, sooner or later leading to disorder..." and although many things can occur, "...one of them is the spontaneous emergence of complexity...".[377] In the first global era, the formation of extensive trade networks emerged out of a single system that served as a base for the development of two other interconnected secondary subsystems. One such subsystem was the Atlantic-Mediterranean area; the other was the Indian-Pacific.[378]

The business activities of commercial companies such as the East India Company[379] and the VOC,[380] along with other far more closed models, including those of Portugal and Spain, favoured the European control of trade throughout the region,[381] to the demise of the old native networks that were initially used by the new model and later eliminated. A market control by means of an "accumulation of knowledge" based on strategies of cooperation and collaboration, and in some cases confrontation. However, at the dawn of the global age, in contrast to monetarist methodological

377   R. Vicente Solé and S. Cuebas Monrubia, *Orden y Caos en sistemas complejos*, (Barcelona: Universitat Politécnica de Catalunya, 2005).

378   J. I.Israel "Mexico and the "General Crisis" of the Seventeenth Century ", *Past and Present*, 63 (1974), pp. 33, explains the relationship of that global system in this way : "... Its purpose was to aid Seville, and the ailing textile manufacturers of Castile, by reducing Mexican textile exports to South America while at the same time reducing the flow of American silver to the Far East through Manila and Macao where Mexican merchants were obtaining their Chinese silks and brocades...". So clearly explain P. Chaunu, *Las Filipinas y el Pacífico de los Ibéricos. Siglos XVI, XVII y XVIII,* (México: IICE, 1974), 20 "... ¿En qué medida la modificación capital del volumen de las llegadas de plata al Guadalquivir entre 1630 y 1640 es imputable al tráfico competidor del Galeón de Manila?...".

379   Vid. some reference works EIC, J. Keay, *The Honourable Company: A History of the English East India Company*, (London: Collins, 1991); B- Gardner, *The East India Company: a History*, (Londres: Davis, 1971) or Ph. Lawson, *The East India Company: A History*, (Londres: Longhmann, 1993).

380   Femme Gaastra, *The Dutch East India Company: Expansion and Decline*, (Walburg: 2003).

381   D. R. Ringrose, *Expansion and Global Interaction, 1200-1700*, (New York: A.W. Longhmann, 2001).

lines, the more optimal approach was different. Rather than a need for capital, there was a need to "accumulate information" to facilitate the boom, the expansion and the future control of the entire market. When capital financing became scarce, it was sought out among the local trade networks and the native oligarchy and elite classes.

Thus, for the base of our study, we have set out to analyse and compare the different models mentioned above. On one hand, there were the two major trading companies, which were developing a new modern capitalism while upholding a certain degree of the old mercantilism,[382] particularly in their dealings with

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[382]   Besides the debate, more pragmatic than ideological about the need for money, also there were other problems of monetary transactions, specifically the Spanish real, William Foster, *A Calendar of the Court Minutes of the East India Company*, (Oxford: Clarendon, Press, 1909), Vol. V, "Petition of Nathaniel Teme, Martin Noell, and other merchant adventurers to the East Indies to the Lord Protector, January 25, 1656. As the trade of India is of great benefit to the English nation and cannot be carried on without large expense and constant supplies of Spanish coin and bullion, and some resentment has been shown lately at leave being given to transport moneys to the East Indies, and a duty laid upon the same, the petitioners have resolved to furnish themselves from Holland ; but, as it may be dangerous, and will be expensive, to send their large ships to receive and carrymoneys from thence, they pray for permission to bring such moneys as will be sufficient for their occasions from Holland in Dutch or other vessels to the Downs, and there lade the same in their own ships bound for India without payment of custom or other ' lett or molestation '. Referred to the Privy Council, Nathaniel Bacon. Arguments of Nathaniel Temes, Martin Noell, and other merchants to induce the protector to grant their Petition. Payment of custom for silver and gold transported to the East Indies is a new thing, for when Queen Elizabeth, King James, King Charles, and the late Parliaments gave licence for such transportation no custom was demanded or exacted by either farmers or commissioners, ' notwithstandinge that the custome should have gone into the private purses of the respective farmers and not into the Exchequer. The trade of India is of high concern to the English nation and cannot be carried on without large and constant supplies of money, and His Highness, who has often shown a gracious propensity to encourage and enlarge trade, may please to know that the fastninge theire plummetts or weights of custome at the heels thereof, 'twill never be able to soar soe high as otherwise it might'. Their Dutch competitors are exempt from such charges and are allowed to send out what moneys they please ; therefore vast sums are imported and to be found in Holland at easy rates. The petitioners plead to be permitted to provide themselves with moneys from Holland, so as not to exhaust the treasure at home, but to ease it by the great sums which will be paid for custom and excise on the goods to be returned in their ships. What they desire will not prejudice the State, but will be of great convenient to themselves and prevent the hazard of sending their large ships to Holland. They have engaged deeply in the trade to India and cannot now find, either in London or the country, a sufficient quantity of rials of eight or other fitting specie, and what there is would be at dearer rates than in Holland".

each other; and on the other hand, the Hispanic model, which was completely mercantilist.[383] We also examine the dealings between the representatives of each model and the kingdoms and merchants of the area.[384] To do so, our first step entailed the development of a database covering trade in the port of Manila throughout the entire 17th century. The fields generated for such purpose include the ports of origin of the vessels; the ship type; the name of the ship owner and his/her nationality; the freight, its type and its value; among others.

Once prepared, the database and its implementation in a Geographical Information System will afford us a comprehensive analysis, with certain perceptions and views that a conventional one would leave out. These include a generous number of analytical variables, ranging from graph theory to market potential. Moreover, the reading offered by such GIS will be far more extensive, as it can be compared with others, such as the volume of ships that reached the Japanese port of Nagasaki[385] (which will greatly facilitate a comparison of the port-to-port dynamics in the Pacific region); the exports of silver from Hirado[386] to Batavia, the large Dutch

383   Archivo General de Indias, Sevilla –AGI-, Filipinas 329 L2, fol. 299, "Remedio para que no vaya más plata de México a Filipinas, 15 de junio de 1619".

384   Vid. J. M. Seguí and J. M. Petrus, *Geografía de redes y sistema de transportes*, (Madrid: Síntesis, 198): 42 "…El análisis de la forma y conexión de las redes y los niveles de jerarquización pueden efectuarse mediante la aplicación de la teoría de grafos…"; for markets vid. M. Potrykowski, *Geografía del Transporte*, (Barcelona: Ariel, 1985).

385   E. Sola, *Historia de un desencuentro: España y Japón, 1580-1614*, (Madrid: Fugaz Ediciones, 1999).

386   There are many works on Hirado and Japan, including, W.Z. Mulder, Hollanders in Hirado, 1597-1641, (Fibula-Van Dishoeck: 1992); J.W. Hall, *The Cambridge History of Japan*, (Cambridge University Press, 1988); A. Farrignton, *The English Factory in Japan*, 1613-1623, (London: British Library, 1991); C.R. Boxer " When the Twain First Met: European Conceptions and Misconceptions of Japan, Sixteenth-Eighteenth Centuries", *Modern Asian Studies*, Vol. 18, No. 4, pp. 531-540, explains "…Jacques Specx, the first Dutch Factor in Japan, writing from Nagasaki on 3 November 1610, reported: The Great Ship coming from Macau usually has about 200 or more merchants on board who go ashore at once, each one of them taking a house wherein to lodge with his servants and slaves. They take no heed of what they spend, and nothing

commercial base in southeast

Asia; and, to take a case in point, the origin of Chinese products; as well as the study of the productive "brands" from Canton and their distribution in Manila, among others.

Different scholars, including Chaudhuri,[387] have clearly and emphatically underscored the manner in which those trading companies, the EIC and the VOC, were actually the true precursors of modern capitalism.[388] We also aim to compare the different policies applied by such companies to ensure their access to the markets in Southeast Asia, with the other more closed and still mercantilist policies of Portugal[389] and Spain.[390] No doubt, the divergent models, the different economic policies of the respective mother countries and their clashes led to great change, not only in Europe, but also far more spectacularly in the Indian Ocean and the Pacific. With reference to such commerce – and the rivalries that

is too costly for them. And sometimes they disburse in the seven or eight months that they stay in Nagasaki more than 250,000 to 3.000.000 taels, through which the populace profit greatly...", p. 532.

387   K. N. Chaudhuri, *The Trading World of Asia and the English East India Company*, (Cambridge: Cambridge University Press, 1989).

388   Vid. E, Arrighi, B. Silver and I. Ahmad, *Chaos and Governance in the Modern World System*, (University of Minnesota Press: 1999); S. Chaudhuri and M. Morineau, Merchants, *Companies and Trade: Europe and Asia in the Early Modern Era*, (Cambridge: Cambridge University Press, 1999).

389   A. Russell-Wood, *The Portuguese Empire, 1415-1808: A World on the Move*, (Baltimore: JHU Press, 1998).

390   AGI, Filipinas, 320, L2, fols. 118-120, "Petición de informe sobre comercio de España y Filipinas". Explaining in fol. 119 "queja por parte de la universidad de mercaderes de Sevilla que se ha representado porque el comercio de Indias estaba decayendo a causa de la mucha contratación que había entre Nueva España y Filipinas y que sería más conveniente desviar ese comercio desde España a Filipinas por el Cabo de Buena Esperanza". The policy of Hispanic Monarchy was limitation,Vid. AGI, Filipinas, 341, L7, fol 6v.-7v. "Petición de informe sobre el comercio de Filipinas, de 20 de marzo de 1660". The Hispanic authorities wanted "….el clavo, canela y otros géneros que eran de contrabando en la carrera de Filipinas por ser a favor de Portugal se comercien en dicha carrera con Nueva España…".Years before, in contradiction with their own political ideas of balance with Portugal, the same metropolitan authorities had issued an order that is grown in the Philippines nutmeg and cloves, vid. AGI, Filipinas, 330 L4 fols. 132r-133v. "Orden para cultivar nuez moscada y clavo en Filipinas, 16 de diciembre de 1639", y ello "…según la propuesta de Juan de Arriola, que se ponga en práctica".

emerged among the different European companies and states –, the
memorandum that the EIC sent to the English authorities describes
the situation in three points: 1) It was extremely dangerous to alter
trade; 2) Thirty-five years of ongoing trade had deeply modified the
European mercantile system and the consumption of spices, leading
to a fifty-percent drop in prices; 3) If the Dutch had the monopoly,
they would raise prices. In essence, these were the observations
transmitted by the East India Company[391] to the English crown. We
will also see the manner in which certain cooperative activities
among the local merchants were gradually eclipsed by a new
economic system and by a new approach to the conception of
global trade, yet above all, with a new recipe for the penetration
and domination of both regional and transnational markets. One
example of the connections that were established between these
two subsystems was the increase in the traffic of Mediterranean
coral. While selling pepper in Genoa, Livorno, Venice and other
Italian cities, the English purchased coral for subsequent resale in
India.[392]

[391]   William Foster, *A Calendar of the Court Minutes of the East India Company*, (Oxford: Claren-
don, Press, 1909), Vol. II, p. 207.

[392]   William Foster, *A Calendar of the Court Minutes of the East India Company*, (Oxford: Clarendon,
Press, 1909), Vol. III: "A Court of Committees, August 5, 1640. The Governor reports the consent of the
generality to pepper being sent to Leghorn and Venice upon the Company's account ; whereupon, after
much debate, the order is submitted to. Though formerly upon like occasions the Guidanaes have been
employed, now upon the special recommendation of several Committees the disposal of such part of the
800 bags of pepper as is to be sent to Leghorn is entrusted to Job Throgmorton and John Collier; and
it is resolved to consign the proportion for Venice to Signors Laurenzo Peti, Romulo Romuli, and Paul
del Sero. Messrs. Bodilo and Martyn, masters of ships, are treated with about freight of their vessels for
transportation of the said pepper ; but they asking too much, no agreement is made, and the Deputy is
entreated to speak with Mr. Bodilo at the Exchange and offer him 1,000 dollars for freight of 500 bags of
pepper to Leghorn, to be laden within six days, and he to undertake to go direct to that port". Also "A Court
of Committees, November 11, 1640, A relation, drawn up by Mr. Hunter, of the state of the Company's
trade to the southwards, is read and referred for future consideration. Proposal is made to write to Mr.
Throgmorton and direct him, if the pepper is sold at Leghorn, to return the proceeds in rials of eight rather
than by exchange, but if it is not sold then to take up at interest money to the value of the said pepper (over
and above the price of the coral) and send it in rials of eight to arrive about next February" and finally the

In our study, we examine the files of the General Archive of the Indies, specifically those pertaining to the "Champagne Registries" of the port of Manila. These files provide more detailed information than the Accounting Section, specifically on the Almojarifazgo series, which was researched by Pierre Chaunu in the 1960s.

Indeed, in his work, "*Las Filipinas y el Pacífico de los Ibéricos*", Chaunu studies trade in Manila based on the sequences of taxes of the Accounting Department. However, the searches conducted on the ships themselves were far more complete, with tremendously exhaustive and finely detailed information. Not only are there more records – in terms of both the number of ships and the capital invested in goods – than those detected by Chaunu, but the ports of origin are far more specific, as is the information pertaining to the ship owner, the products they carried, their value, the crew, the cooperation among the crew members, the vessel's defence strategy, and other information. We have recovered all of this data to generate a far deeper and more comprehensive profile of that trade, centred exclusively on the 17th century, at the very height of exchange, yet also at the time of the sudden decline in trade and the first serious efforts of King Charles II of Spain to revive it, in what has come to be known as "Austrian reformism". Though this does not invalidate the studies by Chaunu, as his work generously takes in the period between the 16th and the 18th centuries, it does approach the subject from a different perspective, in a far more extensive and above all, more analytical set of circumstances.

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agreement by A Court of Committees, June 30, 1643, Advices to be sent to Leghorn and Genoa for coral to be provided to the value of 20,000 or 24,000 ducats".

Trade in Manila

The economic dynamics of the Spanish Monarchy in the Philippines was the result of the variance between two very different political groups with disparate objectives[393]. On one hand was an extremely imperialist group that that had set out to expand itself militarily beyond the islands,[394] leading to the partial occupation of Hermosa Island (Taiwan).[395] This group also considered the possibility of conquering Cochin China and in part, China. On the other hand were those who simply wished to abandon territorial expansion[396], with the aim of strengthening trade relations among all the kingdoms in the area[397] and reactivating Philippine trade with as few obstacles as possible. In this very aspect, there were tragic moments for Manila's trade, to the point in which its authorities attempted to establish diplomatic relations by their own means, to promote trade with strategic areas, as was the case of Siam, and particularly Japan, and thus overcome the chaotic economic milieu of the time. The divergence between these two visions, between these two conceptions of Spanish presence in Asia, ended with the partial triumph of the latter, as the shipping and exchange of goods was the priority focus, though trade between the Philippines and

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393   Vid. J. Headley, "Spain's Asian Presence, 1565-1590. Structures and Aspirations", *Hispanic American Historical Review*, Vol. 75, Nº 4 (1995), pp. 623-646.
394   AGI, Filipinas, 329-L, fol. 60 r. "Petición, del 17 de noviembre de 1607".
395   AGI, Filipinas 330 L4, fols. 218-220, "Respuesta del gobernador de Filipinas sobre la pérdida de Isla Hermosa el 18 de enero de 1648".
396   AGI, Filipinas, 330 L4, fols. 153-154 "Orden sobre la rebelión de Portugal y propuesta a Macao, 14 de julio de 1643".
397   Vid. M. Fernández Gómez, "La misión Keicho, 1613-20 " *Studia Histórica* 20 (1999), pp. 269-296.

New Spain[398], and by extension, all of America[399], was limited. This led to a highly regulated[400] and excessively rigid mercantilist policy that had virtually nothing to do with the interests of the traders of the Philippines and New Spain – or even those of Peru.[401] Needless to say, this policy also greatly differed from the policies developed and implemented by the major European companies that by then had a strong foothold in the area, thanks to their dealings with investors from the native elite classes.[402]

[398]   AGI, Filipinas, 329 L2, fl. 1-22, "Amonestación al gobernador, 17 de septiembre de 1621", the galleon San Juan Bautista came in Acapulco with a cargo of 1,000 tons, far more than permitted. AGI, Filipinas 330 L4, fols. 196-197, "Orden para que se investigue los fraudes de los oidores", as the Court wanted "…se averigüen secretamente las cosas de Diego de Larrasa, Diego Afán y Sebastián Caballero de Medina, que andan siempre juntos, confederados a favor de sus propios intereses, y mercadeando públicamente…". Vid. Filipinas, 300, L4 f. 127v-128r. "Petición de informe sobre despacho de naos sin registro, 14 de septiembre de 1639". Also AGI, Filipinas 300 L5 fols. 12-17 "Orden sobre naos de Filipinas a Acapulco"; or in AGI, Filipinas, 340 L5 fols. 20-22 "Orden para el repartimiento en las naos".

[399]   In 1604 merchants from Manila, sent a letter to the king asking not to charge 10% on clothing that was sent to New Spain, AGI, Filipinas, 339L-2, f. 287 v. Also in AGI, Filipinas 340 L5, fols. 36-40, "Petición de informe para abrir comercio con Perú, 14 de febrero de 1640", In this case the argument was "…para reabrir el comercio de Perú con Nueva España y reparar los daños que sufren las Filipinas.

[400]   Robert Smith, "Spanish Mercantilism: A Hardy Perennial", *Southern Economic Journal*, Vol. 38, No. 1, (1971), pp. 1-11. …". To prevent the export of silver the Court tried to make some changes and innovations. Vid. AGI, Filipinas 329 L2, fols. 128r.-128vto. "Orden para enviar a España semilla de seda de la China", because according to reports obtained it was known of the existence "…de una semilla de seda que hay en la China mejor de la que se conoce en España, se envíe dicha semilla con explicación de cómo se cría…".

[401]   Richard Boyer, "Mexico in the Seventeenth Century: Transition of a Colonial Society", *The Hispanic American Historical Review*, Vol. 57, No. 3, (1977), pp. 455-478, "There were other aspects of Mexico's influence over Peru. Merchants in New Spain profited by undercutting the monopoly system to Peru; they transferred European imports across the isthmus from Veracruz to Acapulco and then shipped them down the coast to Callao. In addition, Mexican manufactures such as textiles, clothing, books, leather goods, and jewelry, had long been staples in the Peruvian market and were sent from Mexico to Peru in large quantities well into the seventeenth century. This must be stressed because the fact that the China trade grew so rapidly in the latter part of the sixteenth century tends to obscure the less dramatic but impressive growth of 50 to 100 percent in domestic manufactures. Peru, partly to handle this expanding trade with New Spain, doubled its merchant fleet in the period 1590 to 1690", p. 473.William Lytle Schurz, "Mexico, Peru, and the Manila Galleon", *The Hispanic American Historical Review*, Vol. 1, No. 4, (1918), pp. 389-402, "In the Calle de Mercaderes, or Street of the Merchants, in Lima, the luxuries of Europe and Asia could be found in the forty shops, some of whose owners possessed a capital of over a million pesos. In 1602 Viceroy Monterey described to the King the luxury of the capital of the great viceroyalty" p. 394.

[402]   Chaudhuri, op. cit. p. 143.

Indeed, while the EIC and the VOC were setting up factories, entering agreements with kings, the nobility and merchants for both the traffic of goods and the investment of capital, and sending commercial agents to the main marketplaces, Spain was setting limits on freight, prohibiting Spanish merchants from engaging in direct trade with certain regions, and in some cases, upholding a pro-Catholic policy that led to major changes in the commercial networks. One example of this religious policy can be seen in Japan, as Dutch rivals used the country as political propaganda[403] in an effort to censure Hispanic imperialism and its consequential evils in Europe. Such displays stirred tensions for the Japanese crown, particularly at a time in which Spanish monks were entering Japan with no authorisation from either the Spanish or the Japanese authorities.[404]

It is true that though the EIC and the VOC adopted a cooperative policy with other agents, they also combined their approach with military activity[405]and occupation, as well as direct conflict in the final death throes of mercantilism. However, it is also true that the Spaniards who had settled in the Philippines promoted commerce and transnational relations, yet they also saw themselves forced to engage in certain military occupations that gradually faded out through time. Thus, there were two totally conflicting formulas. On one hand, the budgets of the Dutch and the English, which, through cooperation, sought to acquaint themselves with and later dominate the Asian market, "to grasp" the vital pulse

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403   AGI, Filipinas, 329 L2 , fol. 140-141 "Orden sobre los peligros de los holandeses en Japón".
404   AGI, Filipinas, 330 L4, fols. 135-136v." Orden sobre el pase de religiosos a Japón".
405   AGI, Filipinas, 300 L4, fols 138-139v. "Orden para socorrer a Malaca atacada por los holandeses". It was vital for the monarchy to maintain control of Malacca as it was a town "….de gran importancia conservar pero que no haya fraude y no se introduzca la contratación entre ambas partes con pretexto de socorro…".

of the entire region, of the entire system, viewing it as a whole and developing an extensive network of agents and collaborators throughout. On the other hand was the Hispanic model, which fostered a "restricted" trade that would not alter in any manner whatsoever the interests of the major merchants of Seville[406], and that would not generate further problems in what was already in itself a depleted Atlantic traffic: "... *Spain's business and trade with the Indies, particularly with New Spain has lost profits, due to the heavy bulk of the goods that were brought from the Philippines, meaning that the consulates and merchants of Seville at different times and on different occasions...*"[407]. The idea was to keep America absolutely dependent on the motherland, and to make an attempt, though in vane, to mitigate the local problems that were emerging as a result of the global market.

Throughout the 17th century, trade in Manila was shaped by two major stages that were directly tied to both the political future of Spain and the internal tensions of each of the hub's trade regions. First of all, the integration of Portugal into the Spanish Kingdom hastened considerable changes not only in trade from the Philippines, but also in the strategy that was adopted by the mother country, which saw a model in the dynamics of the English and Dutch companies, particularly with regard to the use of capital.[408]

406   Lutgardo García Fuentes, *Los peruleros y el comercio de Sevilla con las Indias*, (Sevilla: Universidad, 1997).

407   AGI, Filipinas, 14 "*Carta a SM de Antonio de Morga, Quito, noviembre de* 1615".

408   Chandra Richard da Silva, "The Portuguese East India Company 1628-1633", *Luso-Brazilian Review,* Vol. 11, No. 2, (1974), pp. 152-205, "…In the early 1620's the idea of a company provoked considerable discussion. Schemes for such an organisation were sometimes quite extravagant. For example an anonymous report written about this time proposed that the newly formed company be given the right not only to organise the oriental trade but even Portuguese commerce with most of Europe. Individual private merchants were to be allowed to transport their goods in the ships of the company but would have to pay freight and duties. This particular scheme envisaged even the construction of forts by the agents of the new organisation. The trend of opinion was turning in favour of establishing an East India Company. The large dividends announced by the Dutch V.O.C. underlined its great commercial success. The powerful

Among the commercial changes, the union of the crowns made it possible for the arrival of commercial vessels from the Portuguese possessions in India, yet above all from Macao.[409] Without a doubt, this further activated trade in the city of Manila, only to disappear again completely with Portugal's separation from Spain. Despite these two major stages, which to some extent determined the history of trade in the Port of Cavite, most transactions were made with ports in China, particularly those of Canton and Amoy. The Chinese market became one of the main suppliers of products for the Philippines – as well as for the Portuguese in Macao – and thus received large amounts of silver. As a result of this dependence of Philippine trade on China, the islands became a commercial hostage of the internal dynamics themselves and of Beijing's tug-of-war policy, which oscillated from open to exclusivist. It is also true that China's hunger for silver was not limited to the Philippines; Japan was the main hub for the entry of precious metals, with an even higher trade volume.

Our observations are based on the detailed study of all the vessels that entered the port of Manila throughout the 17th century. This has enabled us to establish a number of fields that paint an overall picture of the trade network.

First, we collected the year-by-year information on the vessels that entered the Port of Cavite; their departure port (georeferenced) and geographical area of origin (georeferenced); their owners; their nationality; the value of their freight and the type of ship.

Spanish minister, the Count Duke of Olivares had grown favourable towards the idea of trading companies operating under the patronage of the Crown.

409   Vid. E. Brazao, *Apontamentos para a història das relaçoes diplomaticas de Portugal com a China*, 1516-1753, (Lisboa: 1949): 227. Also W.E. Cheong, *The Hong Merchants of Canton: Chinese Merchants in Sino-Western Trade*, (London: Routledge, 1997).

In our second step, we drew up a complete and exhaustive list of the freight of each of the ships, which would enable us to determine the volume of each product and to make a global comparison of the types of products that were transported.

Our third step consisted of a follow-up, covering certain specific years of the two fundamental pillars of Manila's trade: the distribution of goods in the city and the productive and export "brands" from the port of origin, namely, from Canton.

Finally, the comprehensive information in the GIS will give us extensive results of Philippine trade, which we can then compare with other studies on the trade of ports in the region, such as Nagasaki[410], Hirado[411] and Bombay[412]. At the same time, it will also enable us to compare the two commercial subsystems, their activity and their repercussions on the global trade system.

Manila: trade volume

In the mid-17th century, between 1620 and 1686, we see a large volume of both capital and vessels, yet at the same time three critical phases. The first phase took in the years between 1622 and 1624; the second between 1629 and 1631 and the third between 1637 and 1641. These phases marked a significant retrenchment of trade in Manila. Yet such retrenchment would become an absolute crisis

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410   In Nagasaki we used data provided by Ryuto Shimada, *The Intra-Asian Trade in Japanese Copper by the Ducht East India Company during the Eighteenth Century*, (Brill:2006).
411   In Hirado, the figures used are those given by L. Blussé, "No Boats to China. The Dutch East India Company and the Changing Pattern of the China Sea Trade, 1635-1690", *Modern Asian Studies*, Vol. 30, No. 1, (1996), pp. 51-76.
412   Other data, such as Bombay, are of K.N.Chaudhuri, *The Trading World of Asia and the English East India Company*, (Cambridge: Cambridge University Press, 1989).

as of 1643[413] when market lethargy set in, due to two circumstantial ruptures: the loss of connections with India, Malaysia and Macao following the Portuguese secession from the Spanish Monarchy and the economic retrenchment of the Chinese market, as a result of its own domestic situation. As displayed in the attached graph, at the height of splendour of Philippine trade, between 1631 and 1636, 84% of the ships that entered Manila came from China and only 2% were from India, whilst Malaysia was becoming the second most important hub.

The data obtained have enabled us to evaluate trade during the era of splendour, specifically between 1631 and 1639. At such time, the port of Manila received an average of 40 vessels per year, with an average annual freight worth one million Spanish pesos. Yet the city would enjoy a spectacular momentary resurgence in 1642, when freight exceeded 1.2 million Spanish pesos. As can be seen, there was a trend of constant growth from the decade of the 1620s to the peak in 1637. As of this date, Manila's trade with all the other ports in the region would suffer severely[414], though it is also true that efforts were made to enter other trade areas, particularly Cochin China and Macassar, and even to exchange with agents that were completely off limits, as was the case of the English.[415] This situation was not only caused by the Asian circumstances, but also by the incapability of both the logistics and the vessels of

413   AGI, México, 22, "*Carta al rey sobre Hacienda*".
414   Vid. AGI, Filipinas, 330 L4, fols. 203r-204v
415   AGI, Filipinas, 330 L4, fols. 191-192, "Advertencia sobre admisión de ingleses para comerciar". AGI, Filipinas, 330 L4, fols 203-204, "Represión a la Audiencia de Manila por permitir comerciar con extranjeros", 1649. This is a "…reprobación por dos pataches ingleses y dinamarqueses procedentes de Zurrate…". AGI, Filipinas, 330 L4, fols. 244-245 "Respuesta sobre comercio con ingleses, 26 de febrero de 1650". The explanatory argument: "…se les permitió porque ofrecieron abastecer a los almacenes con productos de Macassar…".

the Spanish crown, which eventually came to make deals with the English for the hire of boats and marinas for its trade in Asia. This issue was taken up in the general court of the East India Company in London, under the argument that such collaboration would create enemies for them and prove detrimental to their business in the area.[416] This limitation would impact virtually all areas of the political, economic and social spheres, not only in Manila, but also in the market of Acapulco and Mexico, leading King Charles II of Spain to set up and implement plans for economic and commercial recovery, based on a diversity of factors: embassies, trade agreements, reduced obstacles, greater permissiveness in commerce, and similar initiatives.

Undoubtedly, rather than a single cause, there were many factors that contributed to this crisis. These included: the mercantilist policy of the Spanish authorities, which was

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[416]   William Foster, *A Calendar of the Court Minutes of the East India Company*, (Oxford: Clarendon, Pres: 1909, Vol. II), " Setting forth that by this means a way would be opened for the King of Spain to obtain from England a great number of ships and mariners and to entice merchants and others with fair promises of large hire and wages, which ships and men would be used by His Spanish Majesty and the Portuguese to transport goods and merchandise from place to place. This the friends and allies of the English, who by the King of Spain are treated as enemies when they are surprised and overtaken on that side of the line, would not approve of, as being contrary to the common practice that all who sail from one enemy's port to another are looked upon as enemies, and it might therefore be the cause of trouble. That the King of Spain, having done this, might put in the ships so obtained Spanish and Portuguese officers and employ them contrary to the will of the King of England and of their owners, this intention having been manifested in 1639". These references also are in the "*Memoranda concerning an open and free trade to the East Indies, 1640*", explaining "Showing that if the King permits such a trade the following ill effects will ensue, transportation of English ships and sailors into the Spanish service and power, where by contentions and hostilities may arise between the English and other confederate nations. Damages and hazards to His Majesty's subjects by these men and ships being forced into services contrary to the royal will. Diminution of customs by East Indian goods being scattered to foreign parts and not brought into His Majesty's dominions. An aversion in the English to the discovery of unknown places which they might appropriate to His Majesty's and their own use ; with an uncertain and excessive valuation of all East Indian commodities. These and other reasons against an open trade seem especially to concern the King and his subjects, who by the many interruptions and injuries done to them by the Dutch are kept down in their negotiations and forced to relinquish that trade, wherein one year's omission is about three years' loss in the great benefit which may be received from it".

coercive rather than flexible with all the merchants in the zone[417]
including the Philippine merchants; the increase in tax pressures
on the merchants; the increase in the trade of the major European
companies,
such as the EIC and the VOC, which was spectacular in certain
areas; the loss of the Japanese market[418]; China's domestic situation,
which was highly convulsive at the time; and Portugal's separation
from the Spanish crown, among others.

In the midst of this economic milieu, and as can be seen
below, Manila conducted most of its trade was with China.[419]
Nevertheless, in certain periods, particularly during the sixty-
year union between Portugal and Spain, the Philippines also had
occasional dealings with the Portuguese possessions in India,
though chiefly with the great commercial hub of Macao.
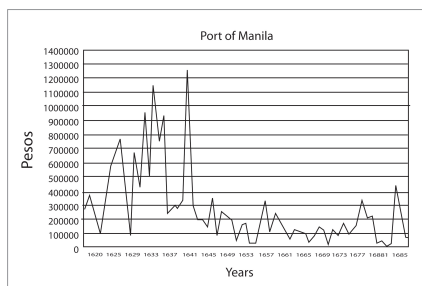
Source: Data from the AGI

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417   AGI, Filipinas, 340, L 3, fol. 285 vto. "Carta de Francisco de los Ríos Coronel a S.M. sobre el comercio con Japón, 5 de septiembre de 1620".
418   AGI, Filipinas, 8-R-2-N-23 "Carta de Cerezo Salazar sobre Japón y China, 8 de octubre de 1634", fol. 1.
419   Vid Alfonso Felix, *The Chinese in the Philipines, 1570-1770* , Vol. 1. (Historical Conservation Society: 1986).

Source: Data from the AGI.

Source: Data from the AGI.

Source: Data from the AGI.

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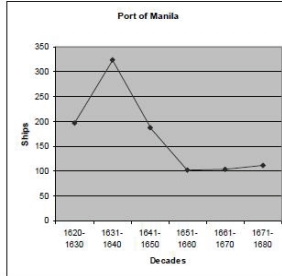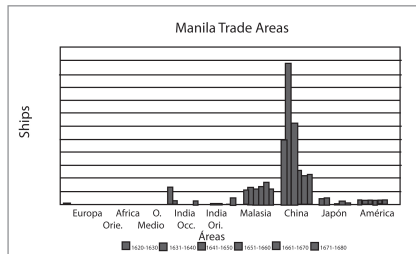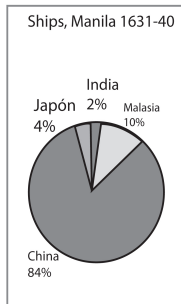
Manila and the export of silver: A myth in trade?

For decades, scholars defended the fact that Manila was the great central hub of trade with China, one of the ports that would even make it possible to expand the so-called "price revolution" into the inland areas of Asia. To some extent, such assertions were based on halftruths, as the issue was approached from the single point of view of Spain's insertion into the Philippines. Nevertheless, we might pose the question: Did Manila's trade in fact have such heavy impact on the rest of the Pacific? Though Manila was a central port, it was not the most important one. In fact, there were many other ports that surpassed it in terms of commercial traffic (for both imports and exports), economic influence and political scope. It is also true that there were times in which the Spanish silver 8-real coin was a transnational currency that was exported in large quantities from Manila to China and other places in Asia. All the same, it must be borne in mind that though the English, to take a case in point, negotiated, paid and purchased with Spanish currency, and specifically with 8-real coins, there was a huge amount of silver from the Japanese market that was circulating throughout Asia, and particularly throughout China.

If we compare the port activity of the different marketplaces in the Indian and Asian region, we will see that neither the impact of Manila, nor the total amount of the silver exported to China could compare to the others in the area. For example, in some cases, Nagasaki[420] had 2-to-4 times more traffic than Manila, and Japan's trade relations were far more extensive and diverse than those of

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[420]   Oka Mihoko, "A great merchant in Nagasaki in the 17th century. Suetsugu Heizo II and the system of respondencia", *Bulletin of Portuguese/Japanese Studies*, 2 (2001) pp. 37-56.

the Philippines. This greater activity could not be attributed to an increase in the arrival of European ships, as they remained stable, having reached a virtual plateau. Rather, what kept the pace of its activity going was the active Chinese trade, which was truly spectacular as of 1683. In a certain manner, each port has its own characteristics, which stem from both its location and its buyer and seller traffic, as Chaudhuri asserts, which is undoubtedly the most important determining factor for the distribution of products.[421]

In the same context, the comparison of the imports from Hirado and Manila is still more surprising. The direct imports of the two marketplaces, paid for in silver and transferred into maravedis, indicates that as of 1636 Hirado was far more active than Manila, with an import rate seven times higher than that of its Philippine counterpart, yet with some decline in the case of Deshima. One factor that explains the high commercial traffic in the Japanese ports was the net profit enjoyed by the sellers.

As regards the production and distribution of the goods that came to Manila from China, and more specifically from Canton, our first basic conclusions are as follows:

1- Canton and its hinterland were undergoing the development of a local industry made up of small craftspeople that produced items for export. Generally speaking, the productive capacity of each in itself was not particularly high, though there were vast differences in productivity among them. In this case, we provide a list of Cantonese manufacturers and their products, along with number of the crafted products that were actually sold to the large export companies.

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421   Chaudhuri, op. cit. p. 139.

2- The goods that were manufactured in China were purchased by large trading companies that gradually established themselves as organized commercial associations. Some, such as Chioqua, Poqua, Gonqua and Anqua, had extensive family networks that facilitated the export of those products. These networks were very important, playing a major role in everything from purchasing from local producers and the availability of ships – whether their own or leased – to the creation of sales offices at the points of destination, such as Manila.

3- The major commercial families headquartered in Manila continued to do heavy business, and it was they who developed the main distribution channels for goods. As we have noted above, they set up sales offices in the city and supplied the people, the trans-Pacific merchants and the different native communities of the Philippines.

4.- The distribution table of the products that came into China brings us to an initial conclusion. Though it is true that there was a great deal of trade with America, and particularly with Acapulco, it can also be said that many of the products that arrived from China were redistributed among the local population.

As we can see, the implementation of a Geographical Information System (GIS) for the historical research of the First Global Age will afford us information and enable us to analyse it from different perspectives, providing a deeper and more comprehensive understanding of the trade and alliances of that period. One example of this type of system is the database for the Port of Manila, in which we have compiled nearly 4000 merchant entries featuring a series of factors that will enable us to draw new

conclusions with reference to the economy. These records contain extremely valuable additional information, including the value of the goods, the port of origin, the port of destination, the stopovers, the merchant's territory of activity, the predominant religions, the resultant products, their amounts and their market prices, among other data.

5-Appendix of tables and graphs .-
5.1-Comparison: Manila-Nagasaki
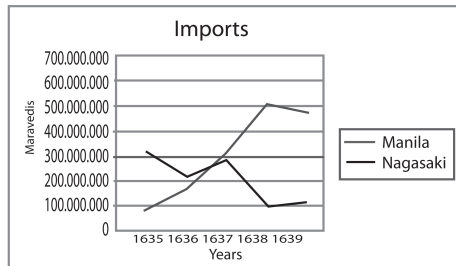
5.2- Comparison, Manila-Hirado.-
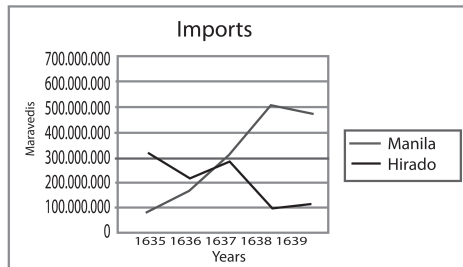
5.3-Comparison: Manila-Deshima.-

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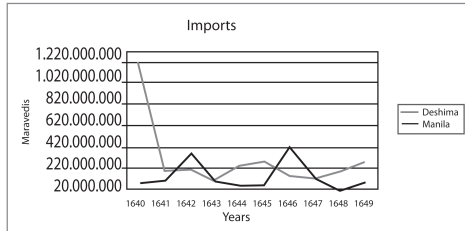
Some value of "branding" producing sales in Canton and Manila,
1686 .-

BUYING IN CANTON CHIOQUA SOLD IN MANILA, BY TRADE, 1686						
Brand	Product	Quantity	Product	Quantity	Product	Quantity
Onglico	Sayas	45	Chaules	15		
Chiangching	Blankets	106				
Bengching	Blankets	41				
Choudingua	Blankets	107				
Cuningua	Tafeta	27				
Yanqua	Bucetas	72				
Guaschigcong	Blankets	115				
Pecsuipin	Linen	114				
Sengui	Thread	93	Small Plates	800	Big Plates	750
Tigua	Blanked	560				
Teginquin	Shoes	270				
Techin	Linen	1544	Trays	108		
Timain	Blanked	300				
Endiguigui	Blanked	340				
Bunsen	Blanked	90				
Dilapre	Copper Wire	206				
Triguan	Thread	200				
Sindiqui	Bucetas	200				
Tianjansua	Paper	3				
Cheyan	Shades	25				
Guachin	Silk	2				
Hiagsinlaia	Silk	46				
Chapdi	Silk	96				

From Small World to Large Universe: Kasimbazar in Eighteenth Century Bengal

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Introduction: Place Histories

Histories of *places* occupy a very minor position within the histories of nations and communities. More so in Southasia where very few records exist prior to the imposition of colonial rule. Yet such histories help us to chart changes, to pinpoint the moment(s) of transition to a new order, or to study global processes in action and on the ground. One manner of studying place-histories of pre colonial Southasia is to visualize their political and commercial worlds in terms of multiple networks created to carry on the business of everyday life: political, social, commercial and financial. Let us turn the lens on Kasimbazar, now a small town near Murshidabad, the capital of the erstwhile Bengal nawabs in present West Bengal state in India (maps 1-4) before the imposition of colonial rule in 1757. Kasimbazar was a seventeenth century silk mart. We find little or no mention of Kasimbazar silks in the trade of the sixteenth century Hussainid state of Bengal with Southeast Asia. The Suma Oriental, the accounts of Duarte Barbosa, Ludovico

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Varthema, Frederici and Fitch, some of our main sources for the sixteenth century, list mainly cottons, sugar and rice as exports from Bengal[422]. Towards the middle of the seventeenth century the situation changed. Kasimbazar may have been a smallish place on the seventeenth century global map but it gradually became a central node in commercial and financial networks in the eighteenth century. These connected with much larger networks emanating from India, Central Asia and Europe and so Kasimbazar became synonymous with global silk trade in the eighteenth century European imagination.[423]

Initially a mart town that supplied the markets of Patna via the fluvial port of Rajmahal,[424] Kasimbazar was "discovered" by the Europeans once the capital of Bengal was established at Maksudabad around 1704. The capital was subsequently renamed Murshidabad by Murshid Quli Khan, a Persian Shi'ite Muslim who was the *diwan* and then the first *nawab* of Bengal. As to why Murshid Quli Khan favoured the actual shift of the capital around 1704-05 as well as the change in nomenclature are not known but we may assume that the first was designed to tap the resources and routes of this potentially rich region and the second to emphasize

422   Tome Pires, *Suma Oriental of Tome Pires, An Account of the East, From the Red Sea to China, written in Malacca and India in 1512-1515 and the Book of Francisco Rodrigues, Pilot Major of the Armada that Discovered Banda and the Moluccas*, ed. Armando Cortesao, 2 vols., (London, Hakluyt Society 1944); Duarte Barbosa, The Book of, tr. M.L. Dames, (London, Hakluyt Society, 1921); Ludovico Varthema, *The Itinerary of, tr. R.C.Temple*, (London, Hakluyt Society, 1928); *Narrative of Ralph Fitch* 1583-91 in William Foster ed. *Early Travels in India 1583-1619*, (London, 1921, reprint, New Delhi, 1968); Cesare Frederici in Richard Hakluyt, *The Principal Navigations* etc., edited by Edmund Goldsmid, F.R.H.S.,Vol. 9, Asia, Part II, eBooks@Adelaide, 2006. Available at http://ebooks.adelaide.edu.au/h/hakluyt/voyages/ accessed May 13 2009.
423   Rila Mukherjee, *Merchants and Companies in Bengal: Kasimbazar and Jugdia in the Eighteenth Century*, (New Delhi, Pragati Publications, 2006).
424   Report of Hughes and Parker 1620-25 in R. C. Temple ed. T*he Diaries of Streynsham Master 1675- 1680 and Other Contemporary Papers Relating Thereto*, 2 vols., (London, John Murray, 1911).

that a new dynasty had emerged in eighteenth century Bengal. The move was advantageous for Kasimbazar as it provided proximity to both mint and court- exceedingly important for merchants and companies.

By the eighteenth century Kasimbazar was known as the great market town whose streets never saw the light of the sun, filled as it was with magnificent buildings.[425] As mart town Kasimbazar was the collection centre for silks produced further inland; and it seems that European demand was a major factor in according Kasimbazar a central place on the mercantile map of Bengal. In 1813 this magnificent city declined as the Bhagirathi changed its course. Soon the area became swampy and malarial and was abandoned. Kasimbazar's history is thus almost an ephemeral history, lasting less than 200 years.

Kasimbazar shows at least five significant periods in its history. From its inception around the middle of the seventeenth century (the actual date is unknown but it was probably around the 1620s and we know that the English East India Company established a factory there in 1658) until 1704 when the capital was moved to Maksudabad; the second from 1704 to 1733 when Bihar joined Bengal *subah* or province; the third from 1733 to 1754, the period of growing trade as well as of, paradoxically, political dislocation; the fourth from 1754 to 1757, the period of transition to a colonial economy and the crisis of proto industrialization; and the fifth from 1757 to 1813, when Kasimbazar slowly became an urban backwater.

Three periods in Kasimbazar's history reveal significant

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425   In Walter Hamilton, *East India Gazetteer*, 2 vols. (London, Parbury Allen & Co., 1828). See vol.1.

shifts in its economy. The first lasted from 1680 to 1704 when Kasimbazar became increasingly important in Asian and Persian Gulf trades. The second was from 1704 to 1733, that is, from the time of establishment of the capital at nearby Murshidabad to the incorporation of Bihar into Bengal *subah* (province), this offered Kasimbazar easier access to north Indian markets; this was also the time when Asians and Europeans entered Kasimbazar in large numbers due to better transport and information networks; and consequently at this time Asian and European networks operated simultaneously and often symbiotically. Lastly, the period from 1733 to 1754 was the period which saw a phase shift where the English East India Company imposed a total control over silk production and trade and this launched the transition to colonial rule. There were corresponding shifts in networks as the players adapted to changed conditions. Let us see what these networks comprised of.

Multiple Networks
Small Networks

In The Enchantress of Florence Salman Rushdie talked of the networks embracing sixteenth century Asia, Europe, and America. In his story of the "Mogol dell Amore", the Mughal of Love, Rushdie referred to networks of war, of adventure, of desire and of avarice that ultimately created a world marked by the circulation of commodities and cultures, of men and money. Networks enmeshed the world and such networks demonstrated links between multiple worlds rather than establishing comparisons between them. Kasimbazar is a prime example of this process.

How do networks organize themselves? Random networks may not always operate with "official' (political or systemic) sanction. Kogut feels, citing Hayek[426], that while market is the engine; it is knowledge, which is specialisation creating value, which underlies efficient networks.[427]

Specialisation creating value and knowledge has been, from time immemorial, key factors in production and trade. The technical, financial (accounting) and organisational knowledge of the silk merchants of Kasimbazar, who were born into the business and nurtured within it, created this value, felt the VOC in 1687: "The merchants...are exceptionally quick and experienced. When they are still very young... .they already begin to be trained as merchants. They are made to pretend to engage in trade while playing, first buying cauris, followed by silver and gold. In this training as money changers, they acquire the capacity of large scale trade"[428]. The English East India and the French East India companies made similar observations on the social and commercial capital the merchants acquired since childhood, by noting that they had been bred in the business since infancy.[429] Their technical knowledge was therefore a community based and historically acquired knowledge that no modern knowledge system could hope to compete with. The East India companies frequently clashed with this knowledge sys-

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426   F. Hayek, F., *The Fatal Conceit*: *The Errors of Socialism*, (University of Chicago Press, 1988).
427   Bruce Kogut, 'The Network as Knowledge: Generative Rules and the Emergence of Structure', *Strategic Management Journal*, Vol. 21, No. 3, Special Issue: Strategic Networks (Mar., 2000), pp. 405- 425. See p. 409.
428   In Om Prakash, *The Dutch East India Company and the Economy of Bengal, 1630-1720*, (Delhi, Oxford University Press, 1988), pp. 104-05.
429   Kasimbazar Factory Records (henceforth K.F.R.), February 28, 1744, India Office Records, London; see also Indrani Ray's articles in Lakshmi Subramanian ed. T*he French East India Company and the Trade of the Indian Ocean, A Collection of Essays by Indrani* Ray, (New Delhi and Calcutta, Munshiram Manoharlal and Centre for Studies in Social Sciences, 1999). Henceforth Subramanian ed. 1999.

tem as the former sought to introduce their own ways of doing business at Kasimbazar. And this specialization and knowledge set in train networks that lasted a century.

Small Worlds

Kasimbazar was initially a "small world" both economically and physically. At inception it seems to have had limited commercial impact within a similarly limited spatial extent. When founded in the seventeenth century by a Mughal official named Kasim Khan[430], soon after the Mughal conquest of Bengal, possibly in 1618 or 1628, it was a small mart town. Its only access was to north Indian urban centres and this was quite restricted but we do know that Kasimbazar textiles were sold in Patna in the 1620s.[431] But while its commercial networks may have been limited at inception, some sort of a transport network was already in place. Goods to and from Bengal already moved through Bihar, up to Agra and Lahore or down to the Bay of Bengal. Ralph Fitch (1583-91) sailed from Agra to Saptagrama in Bengal with a fleet of 180 boats, laden with salt, opium, lead, carpets, etc.[432] Teixeira wrote around 1600 that ships from Cochin arrived at Hormuz to pick up salt destined for Bengal.[433] Jourdain noted in 1611 that 10 000 tons of salt in barges of

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430   There was a Kasim Khan, Mughal *subahdar* of Bengal in 1613 and another named Kasim Khan Jang in 1628, see Walter Hamilton, *East India Gazetteer,* 2 vols. (London, Parbury Allen & Co., 1828). See vol.1. It is not clear which one of them established the town.

431   Report of Hughes and Parker 1620-25 (Vid. ut supra).

432   Benoy Kumar Sarkar, *Inland Transport And Communication In Medieval India*, Printed By Bhupendra.Lal Banerji at The Calcutta University Press, (Calcutta, Senate House, 1925), p. 12.

433   W.F. Sinclair and D. W. Ferguson eds. *The Travels of Pedro Texeira* etc., (London, Hakluyt Society, Second Series, 1902).

400 or 500 hundred tons moved from Agra to Bengal annually; this was echoed by Peter Mundy who noted vessels between 300 and 500 tons plying between Agra and Bengal as far as Dhaka, carrying salt and other merchandise.[434] It was recorded by the EEIC in the 1630s about a ship's voyage that "from Gombroon she is to be sent with a cargo of salt to Masulipatam and Bengal, and thence to bring to Surat a return cargo of sugar, gum-lac, wax, etc."[435] Saltpeter, which was much in demand by the East India companies for making artillery was bought by them in Bihar and then transported to Europe from the Bengal coast. The saltpeter came into Bengal via Rajmahal, the fluvial frontier between Bengal and Bihar: saltpeter was first mentioned as commodity in English records as early as in 1621, in Kerridge's letter to the English East India Company.[436]

Kasimbazar's main trading partners were the north Indian markets and the caravan trade networks that passed through Patna in Bihar into both Bhutan and Central Asia. Access to north Indian markets improved by the mid seventeenth century and it seems that at that time Kasimbazar's financial and mercantile networks became more integrated to those of Agra, a great centre for provisioning both the Mughal court and the international caravan trade. John Kenn of the English East India Company wrote in 1661, emphasizing the close links between the silk and money markets in Kasimbazar and North India, "According as this silk sells in Agra, so the price of silk in Kasimbazar riseth and falleth. The exchange of

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434   Benoy Kumar Sarkar, Op. cit. pp.12-13.
435   William Foster, *The English Factories in India*, 1618-1669, (Oxford, Clarendon Press, 1906-27), volume 5: 1634-36, p. 212.
436   Balkrishna, *Commercial Relations between India and England*, 1601-1757, (London, George Routledge and Sons, 1924), p. 100.

money from Kasimbazar to Patna and Agra riseth and falleth as the said silk findeth a vent in Patna and Agra".[437] Silk was firmly tied to the financial markets. Other northern destinations were Mirzapur, Lahore, Multan, Benares and Delhi. In the south Aurangabad was an important destination, as was Gujarat to the west. Ispahan, or New Julfa, whose network was controlled by the Armenians, was another westward destination for Kasimbazar silk.

Small World Systems

So we see that the shift toward more extensive networks happened from the middle of the seventeenth century, and this is an important point I shall return to later. Maps support the hypothesis that Kasimbazar was not very important in European perception in the first part of the seventeenth century or was perhaps too small to be depicted; I have found few representations of Kasimbazar on seventeenth century maps (one exception is map 1), but plenty in the eighteenth century, emanating from the middle of the eighteenth century (maps 2- 4). This was therefore initially a little world system marked by a limited transmission of information and an equally restricted exchange of goods, mainly of the luxury kind, from Kasimbazar and its neighbourhood, such as silks and mixes of silk and cotton. These were destined mainly for the markets of the north and beyond. Rice to sustain this mulberry land came from nearby Bardhaman district. Dutch control of the Indonesian pepper trade in the early seventeenth century increased the demand in

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[437] B. M. Addl. Mss., 34, 123, f. 42; C. R. Wilson, *Early Annals of the English in Bengal*, vol. I (Calcutta, 1895), p. 376, cited in Sushil Chaudhury, 'International Trade in Bengal Silk and the Comparative Role of Asians and Europeans, circa. 1700-1757', *Modern Asian Studies,* Vol. 29, (May, 1995, No. 2), pp. 373-386. See p. 375.

local Asian markets, particularly Bengal, for Malabar and Kanara pepper.[438]

It is worth noting that both Bernier and Tavernier visited Kasimbazar (although not together) in the 1660s; in fact Shaista Khan, then Mughal *subahdar* at Dhaka, at the far eastern side of the province, gave Tavernier a bill of exchange drawn on Kasimbazar. This last suggests that Kasimbazar was gradually becoming important as a trade mart and financial centre from themiddle of the seventeenth century. Our hypothesis of the emergence of Kasimbazar as place therefore coincides with the date (1658) that the English East India Company set up a factory in Kasimbazar. The French and Dutch companies soon followed suit.

As with its northern networks, initially Kasimbazar's links with the southwestern Bengal delta were few; the ports of Saptagrama and Hugli were its main outlets to the Bay of Bengal. English Calcutta had not yet been founded; it was founded only in 1690. Kasimbazar's links with the southeastern delta were negligible; because when the capital was shifted to Dhaka in the southeastern delta in the 1660s the chief trading items exported from the ports in the southeastern delta were still mainly the cottons and muslins manufactured in the Dhaka region, as well as grains, oils and foodstuff. Silk was barely exported.

And it was a water world! Deloche quotes Greenhill: "during the South West monsoon and for months after it is finished Bengal becomes a world of water... It is the world of men who live three thirds of their lives on the water, a world of men who make voyages taking many months but who never sail the open sea... this world

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438   A. R. Disney, 'The First Portuguese India Company, 1628-33', *The Economic History Review*, New Series, Vol. 30, No. 2. (May, 1977), pp. 242-258. See p. 247, fn 6.

has songs and poetry of its own."[439] You can see from Map 5 that Kasimbazar lies on a branch of the Ganga that is partially navigable throughout the year, and this channel links up with the main branch that is not very far and is fully navigable through the year. Ralph Fitch (1583-91) sailed from Agra to Saptagrama in Bengal by this route, but of course he never visited Kasimbazar as it did not exist then.[440]

This water world was subject to the fluvial shifts that ravaged the province from the fifteenth century onwards. Travellers from the sixteenth century have testified to these shifts. The sixteenth century "first city" of Gaur, then the capital, was abandoned when the river changed its course, and a new capital-the second city of Gaur-had to be constructed on the opposite banks of the river. Tavernier wrote that Rajmahal, the splendid capital and flourishing port of the 1630s, was a wasteland in the 1660s due to the Ganga having changed its course and added that Bernier was forced to go over from Rajmahal to Kasimbazar as the Bhagirathi river too had dried up.[441] John Marshall travelling here in 1670 commented on the shallowness of the river at Rajmahal.[442] This water world was not just an unstable world; it was also a calamitous one, as the Bengal estuary was frequently ravaged by cyclones, causing tsunamis to rise in the Ganga.

Having established that Kasimbazar was ecologically a small world and economically even more so, one largely dependent

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439   B. Greenhill, *Boats and Boatmen of Pakistan*, Newton Abbot, 1971, p. 35, in Jean Deloche, 'Boats and ships in Bengal Terracotta Arts', *Bulletin de l'Ecole Française d'Extrême-Orient*, Volume 78, (Numéro 1, 1991), pp. 1 – 49. See p.3.
440   Benoy Kumar Sarkar, Op. Cit. p. 12.
441   Jean Baptiste Tavernier, *Travels in India*, 2 vols. Ball and Crooke (ed. and tr.), (London, 1889 edition, reprint, New Delhi, Asian Educational Services, 2001). See Book 1, p. 102, p. 103.
442   Shafaat Ahmad Khan, ed. *John Marshall in India: Notes and Observations in Bengal* (1668-1672), p. 69. (Reprint, Read Books, 2006).

on the rhythm of the monsoons and the nor'westerly winds, I would like to underline that this small world was also uncommonly vulnerable to political disturbances. This was evident from the Maratha invasions of Bengal from 1742 and the Afghanrebellion in Bihar, and particularly at Patna, from 1745, both of which sandwiched Kasimbazar from west and north; the first effectively deprived Kasimbazar of its rice supply from Bardhamana in the west as the Marathas proceeded into Bengal and the second meant that trade was stopped on the Ganga at Patna for almost a year. Thereby the passage of goods from North India into Bengal and from Bengal to Agra was disrupted, the mint was often closed and many of the networks fragmented in the 1740s, leaving the Kasimbazar merchants with little option but to undertake more orders from the European East India companies.

Between the sixteenth and eighteenth centuries Kasimbazar transformed from a little "place" to a big "space", and the moment of transformation was around the middle of the seventeenth century. As commercial networks intensified in scope, this small world started on the path to change when Murshidabad became the capital from around 1704. The transportation benefits, from the fluvial network that ran through it and connected to Murshidabad and Patna, were discovered once again. It was through the fluvial network and proximity to the new capital that Kasimbazar catapulted itself into the uppermost rank among silk marts in the subcontinent. So we see that the initial "small world" phenomenon for Kasimbazar was "local centric" and then moved up to embrace the regional and then the national, as we see from an English report of the 1620s.[443] The shift from local to global is documented in maps

443   Hughes and Parker.

of the period, as I show, and readings of contemporaneous texts also confirm this shift.

Global Networks

In 1733 this not so small world expanded further as Bihar became a part of the nawabi province of Bengal. This integration opened up new transport networks and simultaneously, new commercial and financial networks. The Mughal emperor Jahangir had connected Patna to Agra in the seventeenth century, now by virtue of Bihar's integration with Bengal in 1733 the latter too became connected to Agra by way of Bihar. The road from Malda near Kasimbazar linked the commercial areas of Tirhut and Chhapra in Bihar, and Chhapra was only 10 kos (approximately 3.2 kms) away from Patna. We will see later that the Armenians had substantial business interests in the commercially rich region of Chhapra. The older Lucknow-Benares link now joined Murshidabad and Patna to this northern overland route[444].

Why was Patna (and Bihar) so important to eighteenth century Bengal? We have already mentioned the overland routes through Patna that connected Bengal to north India, through the Ganga, now let us look at maritime outlets. In the seventeenth century, when it was a Mughal province, Bengal's two main royal ports were Hugli in the west of the province and Dhaka in the east. The port that faced north, and connected Bengal with north India, was the Gangetic port of Rajmahal, sometime capital in the 1630s. This was a port that experienced "great trade" in the seventeenth

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[444]   Kumkum Chatterjee, *Merchants, Politics and Society in Early Modern India, Bihar* 1733-1820, (Brill, 1996), p. 15.

century but it was a secondary port, far from the Bay of Bengal
and functioning only as a transit point in communications and
trade between Agra and Bengal. In the eighteenth century, when
the rich province of Bihar became a part of Bengal province, the
annexation was of immense strategic value because Bengal now
had easy access to the northern provinces of Awadh, Delhi and
Agra through Bihar's capital and port Patna, which lay on the
Ganges. New transport networks, and along them new commercial
and financial networks, were set up linking Bengal with Bihar and
northward with Mughal India, or, conversely, Mughal India with
the Bay of Bengal.[445] The four ports of Bengal were now Hugli (under
an official named Baksh *Bandar*), Dhaka under the Shah *Bandar*,
Murshidabad under the Pachotra *Bandar* (or Pachotra Daroga as
referred to in the Kasimbazar Factory Records of the English East
India Company) and Patna under the Budrekha Bandar. This last
controlled all duties from trade from the upper and middle Gangetic
routes and ports, so we can imagine the enormous profits accruing
to Bengal with the incorporation of Bihar into the province.

Moreover, the export of Bihar's many products, namely
saltpeter, sugar, rice, poppy and cotton cloths, now acted to the
financial advantage of Bengal. It is no accident that we find a
number of 'up country', i.e. Bihari and north Indian, merchants
operating from Kasimbazar from the late 1730s; these merchants
brought their financial expertise and business acumen to Bengal
and enriched trading possibilities there. Among these, the houses of
Jagat Seth and Alamchand were the most successful, by expanding
their operations to the east, west and north of the province and
beyond, they organized a mercantile and financial web through

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445　See Kumkum Chatterjee, Op. cit. 1996.

the system of hundis (bills of exchange) that guaranteed payment
against goods anywhere in north India and the Deccan. There is a
Hiranand Shahu ki Gali (the Lane of Hiranand Shah) in Patna even
now; Hiranand was the founder of the house of Jagat Seth.[446] Such
is the way that networks live on in public memory.

It has been argued that the European merchants were
not the chief trading partners of eighteenth century Bengal.
Merchants from other parts of the subcontinent based themselves
in eighteenth century Kasimbazar: they were first and foremost the
Gujaratis, subsequently came the merchants from Lahore, Multan,
Benares, Gorakhpur, Delhi (Calwars) and Agra from the north,
from Hyderabad in the Deccan, as also merchants from Jangipur
in Murshidabad district, the last probably acted as gomastas or
agents of Benares merchants[447]. In April 1712 we have a reference
from the English East India Company records of merchants from
Lahore meeting Manickchand, the founder of the house of the
Seths.[448] By the middle of the eighteenth century this list expanded
to accommodate even more merchants from the subcontinent:
"Cashmeerians, Multanys, Patans, Sheiks, Sunniasys, Paggayahs,
Betteeas and many others used to resort to Bengal in Caffeelas or
large parties of many thousand together with troops of oxen for the
transport of goods...".[449] This is clearly a reference to the overland
trade within India that connected to the great caravan routes of
Asia.

446   Ibid, p. 22.
447   Sushil Chaudhury, Op. Cit., 1995, p. 375.
448   C.R.Wilson, *The Early Annals of the English in Bengal being the Bengal Public Consultations for
the First Half of the Eighteenth Century,* (London, Thacker, 1900), V.1, p. 48.
449   Sushil Chaudhury, 1995, p. 383. Grose mentions a host of Asian traders in Bengal at mid
century. See John Henry Grose, *A Voyage to the East Indies* etc., 2 vols. (London, M DCC LXXII), vol.2, p.
234.

The networks of the little studied *sannyasis*, Gosains etc. who controlled the silk trade between Benares, Mirzapur, Bengal, Bihar and the Deccan, and who traded to the northeast between Bengal and Bhutan, are of immense value for our understanding of the organization of silk and other trades carried on throughout Southasia by such mobile groups.[450] The sannyasi network combined two identities; religious and commercial. Because of the former identity, as holy men, they could travel unhindered all over the continent and a large part of the internal circulation was in their hands. It was recorded that the Gosains numbered 10 000 in Benares alone, and in times of pilgrimage (and trade) they numbered up to 35 000.[451]

Silk was a commodity in the true sense of the term. It was obtained through a long information pathway and an organizational chain of production, procurement and transport where various grades of buyers and sellers, many operating through agents, brokers and *banians* functioned. Asian financial systems were major movers in this system. Chaudhury writes that "the supremacy of the Asian merchants (over the Europeans) is also confirmed by one Sadananda Bandopadhyay who was the gomasta of a Gujarati merchant in Kasimbazar and was himself in the silk business for thirty years, who stated, referring to the I750s in all probability, that there were ten merchants in Murshidabad who exported Bengal raw silk to the tune of I3, 000 to 20, 000 maunds annually. It was Louis Taillefert, the Dutch Director in Bengal, who clearly pointed out in 1763 that the procurement of raw silk by the

450   Bernard S. Cohn, 'The Role of the Gosains in the Economy of Eighteenth and Nineteenth Century Upper India', *Indian Economic & Social History Review*, Vol. 1, (No. 4, 1964), pp. 175-182;
451   H.R.Ghosal, *Economic Transition in the Bengal Presidency* (1793-1833), (Patna University, 1950), pp. 183-84.

gomastas of traders from Lahore and Multan had gone up to a great extent since the beginning of the eighteenth century".[452]

Other than Asian merchants there were the Armenians at Saidabad with a large house and garden, in a suburb of Kasimbazar. The Armenians had entrenched themselves in the trade marts and production centres of interior Bengal and Bihar, dealing in silk, opium and saltpeter, from possibly the end of the sixteenth century. The Armenians had networks stretching from New Julfa to Manila, and in the seventeenth century the EEIC established close links with them for trade, financial remittances and access to the court in Bengal.[453] Armenian trade in Bengal was charged less than the usual duty of 5% by the nawabs. Goods from Bengal, mainly textiles, were taken to Madras by the Armenians from where they entered the Madras-Manila-New Spain network of the Armenians.[454] A church dedicated to the Virgin was built at Saidabad near Kasimbazar.

Rooting the Space in Place: Nawabi Promotion of the Economy

If you study any eighteenth century map of Kasimbazar such as the maps displayed at the end of this chapter, you will notice that it is situated in a triangle caused by the Bhagirathi, the Jalangi and the Padma rivers: these riverways facilitated communication with marts and production centres throughout the province. The

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452   Sushil Chaudhury, 1995, p. 382.
453   Sushil Chaudhury, 'Trading Networks in a Traditional Diaspora: Armenians in India circa 1600-1800' in Ina Baghdiantz McCabe, Gelina Harlaftis and Ioanna Pepelasis Minoglou eds. *Diaspora Entrepreneurial Networks: Four Centuries of History*, (Berg Publishers, 2nd edition, 2005) pp. 51-72. See pp. 53-4.
454   Bhaswati Bhattacharya, 'Making money at the blessed place of Manila: Armenians in the Madras– Manila trade in the eighteenth century', *Journal of Global History* (2008, 3), pp. 1–20. See pp. 13-14.

Bhagirathi along this stretch was called the "Cossimbazar River". This island exists no more; the Jalangi has dried up. Because of the easily navigable fluvial highways to Patna in the north and Hugli in the south, transport of goods was easy, both north to the great caravan routes or south to the Bay of Bengal. Because of Kasimbazar's propinquity to the production centres of Kumarkhali in Nadia district (present state of West Bengal, India) and Rangpur (in present Bangladesh), both of which could be easily ccessed by good transport networks (both road and fluvial systems), as well as for having its own silk producing area around Jangipur, Gonatea, Rangamati and Shantipur, the merchants of Kasimbazar were in a particularly advantageous position to furnish textiles of all kinds, but particularly silks, to the East India companies. The locational and transport dynamics ensured that Kasimbazar occupied the foremost position as trade mart in Bengal; the other being Dhaka in the east of the province.

Kasimbazar's advantageous location therefore greatly facilitated its position as the foremost silk mart of Bengal. Its central location supported a hierarchy of mart towns and production centres; these were very great in number. Map 3 shows that eighteenth century Kasimbazar lay in a densely urbanized zone with numerous urban and rural markets to which it was connected both spatially and economically.[455] These markets were also connected via a social network; they were often established and controlled by the royal family and favoured courtiers, financed by local moneylenders (sarafs), powered by local landlords on whose domains they were situated and fuelled by merchants (*dadni*

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455   Indrani Ray, 'Journey to Cassimbazar and Murshidabad: Observations of a French Visitor to Bengal in 1743', in Lakshmi Subramanian ed. 1999, pp. 144-176.

merchants) who transported the goods to the markets.

The ruling class took the lead in establishing markets. Murshid Quli, the first nawab, constructed the Katra Masjid at Murshidabad; this functioned as the central royal market place and subsequently his tomb. Murshid Quli also established the Bhagwangola (wholesale market) near Murshidabad in his grandson Sarfaraz Khan's name; and he also founded, in Murshidabad, J'afargunj in 1708. J'afar Khan was another name of Murshid Quli. Murshid Quli constructed simultaneously the chowk at the secondary capital in the east, Dhaka, to facilitate transactions, and established there the Bazaar Kartalabh Khan, yet another of his names. The next dynasty of Alivardi Khan established even more bazaars; in Bihar the bazaar of Hajigunj was owned by Haji Ahmad, who had substantial commercial interests in Bihar and Bengal, mostly saltpeter and opium and who just happened to be the brother of Alivardi Khan, the nawab from 1740 until 1756.[456]

The ruling class constituted, therefore, a very influential group. The cohesion of this group is shown in the overthrow of Murshid's grandson, Sarfaraz Khan in 1740. Sarfaraz Khan became nawab of Bengal in 1739-1740. But courtiers and financiers such as the Jain Seths, the Hindus Alamchand and Chin Ray at Murshidabad, Muslim generals as well as a handful of less powerful courtier-merchants ultimately switched loyalties and deposed him in favour of Alivardi Khan from Bihar. The point worth noting here is that the more powerful landlords (*zamindars*) of Bengal also supported this move to topple the House of Murshid Quli and welcome a

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456   Rila Mukherjee, "The Nawab's Business: Agricultural and Commercial Practices in Eighteenth Century Bengal" in Chittabrata Palit and Pranjal Bhattacharyya eds. *Business History of India*, (New Delhi, Gyan Books, 2006, pp. xxxii-xxxv.

nawab from Bihar instead, possibly because most *zamindars* had become alienated through Murshid Quli's harsh revenue measures. The switch of loyalties obviously helped the commercial and financial interests of the courtier-merchant-landlord combine at Murshidabad. As Bihar had become a part of Bengal *subah* in 1733 it was deemed suitable, and advantageous, to have a *nawab* from that region. This social network would rule Bengal until 1757, when Alivardi's grandson Siraj ud daulah, *nawab* of Bengal from 1756 to 1757, was murdered by the British and Bengal became a province administered by the EEIC.

Alivardi himself had started his career by entering the Bengal *nawab*'s service; he became the faujdar of Rajmahal around 1728 and in 1732-33 he was appointed as deputy governor (*subahdar*) of Patna. The next year Bihar became part of Bengal and it seems likely that Alivardi Khan was the architect of this annexation.[457] There were now put in place highly complex social and transport networks that linked production centre to market and the mart town to port via ghats (landing place on a river or lake), roads and bridges.[458] Traffic regulations ensuring the safety of peoples and goods, the building of forts in border areas for protection and the setting up of serais helped sustain these communication networks. Enforcement of contracts and the protection of property nourished commercial relations within the province and beyond.[459] A postal system set in motion by the Mughals and then by the *nawab*s, both from Hugli by sea and overland through Patna and Surat, facilitated communication beyond the state.

457   See Jadunath Sarkar, *Bengal Nawabs* (Calcutta, Asiatic Society, 1952).
458   See Tilottama Mukherjee, 'The Co-ordinating State and the Economy: The Nizamat in Eighteenth- Century Bengal', Modern Asian Studies, Vol. 43, 2, (March 2009), pp. 389-436.
459   Rila Mukherjee, "The Nawab's Business": Op. cit.

Map 4 shows Kasimbazar's riverine links with the north
and the northeast of the subcontinent; these fluvial networks
ensured reasonably safe and low transport costs facilitating both
communication and trade.

The port administration, especially the nearby ports at
Hugli and Kasimbazar/Murshidabad were controlled by the Bengal
nawabs and their favourites from 1711, bypassing the emperor's
nominees from Delhi.[460] De Gennes de la Chancelliere tells us that
in 1743 the office of the faujdar (chief port official, under whom the
various bandar or port officials worked) of Hugli was held by the
nephew of Alivardi Khan, then the nawab.[461] Local networks were
becoming significant and the *nawabs*, by controlling the selection
of port officials, sought to control the resources of the province
to their advantage. By buying into bazaars, by establishing new
markets and thereby diverting production and sales from older
centres, by initiating roadways and bridges, and by putting their
relatives in charge of port administration, the *nawabs* sought to
control the commercial and transport networks in the province by
land, river and maritime routes. Other than thus securing the trade
channels of the province to their own advantage, the Bengal *nawabs*
also entrusted the administration of sensitive border areas, such as
Purnia, now in Bihar, to favourites or relatives. To keep prices low,
the export of grain was prohibited; an official checked the amount
of grain carried on board ships departing Bengal against the
number of crew every time a ship departed from any of the ports
of the province.[462] Bengal in the first half of the eighteenth century
was a coherent political unit. It was also economically sovereign

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460   See C.R.Wilson (1895), V.1.
461   Indrani Ray, 'Journey to Cassimbazar' etc. p. 151.
462   Mukherjee, 2006a. See f.n. 79, p. 158.

through networks set in motion by its own needs.

The Phase Transition at Kasimbazar: From Small World to a System through Commodities

Commodities lead increasingly global lives, their spaces are geographic which expand or contract according to networks. Let us look at the lives of commodities in pre colonial Bengal.

From Rice and Sugar to Silk

There are indications that rice, sugar and grain, which formed export staples in sixteenth century Bengal, were becoming dear from the second half of the seventeenth century. Fitch had noted a booming trade in rice and grain from Bengal at the end of the sixteenth century. Cesare Frederici, at the same time, had noted the great export of sugar from Bengal to different parts of the empire.[463]

There seems to have been a break in this commerce from the middle of the seventeenth century. The *English Factories in India* refer to sugar, bees wax, gum lac and cottons being staple, "coarse" exports from Bengal in the 1630s,[464] but from thereon we hear less of these staples, and more of cash crops as export items. Indeed cash crops seem to have dotted the province: Bowrey and de Graaf noted the shift to the production of saltpeter and opium.[465] Yet another cash crop was silk and it seems certain that

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463   Cesare Frederici in Richard Hakluyt, *The Principal Navigations* etc., Vol. 9, Asia, Part II.
464   William Foster, *The English Factories in India,* 1618-1669, volume 5: 1634-36.
465   See R.C. Temple, (ed). *Thomas Bowrey, A Geographical Account of the Countries Around The Bay of Bengal 1669-1679*, (Cambridge, Hakluyt Society, M D CCCC V). Henceforth Bowrey. See pp. 225-29; De *Voyage de Nicolas de Graaf aux Indes Orientales etc*. (1639-87), (Amsterdam, J.F.Bernard, MD CC XIX), p.

the Bengal nawabs wanted to promote silk as an export commodity in the eighteenth century. Mulberry lands were taxed higher than rice lands in eighteenth century Bengal, indicative of the great change that had taken place in the commercial landscape.[466] The Armenians were granted commercial privileges that reduced their export duties from 5% to 3.5%. Sebouh Aslanian however is of the opinion that the Armenians traded in a portfolio of commodities rather than concentrating on a single item (email of April 27, 2009).

Why was there this shift? Were Bengal staples still lower in price as compared to other parts of the Mughal Empire? If not, and we just read that to keep prices low, the export of grain by Europeans was prohibited in eighteenth century Bengal; an official checked the amount of grain carried on board ships departing Bengal against the number of crew every time a ship departed from any of the ports of the province, was the shift to capitalist agriculture reflective of rising prices which made for unfavourable trading conditions of these staples?

The Shift from Silk to Saltpeter:

Saltpeter became a very significant export commodity from the end of the seventeenth century. Bowrey and de Graaf, we read, had noted this. It should be remembered that this was due to European demand; resulting from the frequent wars in Europe in the seventeenth century.

There was little or no Asian demand for this item. In the first half of the century the little known Portuguese East India Company

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71. (Henceforth de Graaf).
466   Om Prakash, *The Dutch East India Company and the Economy of Bengal 1630-1720*, (Delhi, Oxford University Press, 1988), p. 25; Mukherjee, 2006a, p. xxxii.

traded in saltpeter from Bengal, but it was reported that the costs were high as it had to be transported to Goa. Saltpeter was obtained through contract in Bengal and Bihar and we have the names of two contractors there: Oliveira de Morses and Fernao Carvalho.[467]

Saltpeter increasingly rivaled silk as export commodity from Bengal from the end of the seventeenth century. The VOC and the English East India Company were major traders in saltpeter. Saltpeter also served as ballast on ships.[468] Regarding the boats called the patella, Thomas Bowrey wrote: (these are boats) "that come downe from Pattana with saltpeeter or other goods built of an exceedinge strength and are very flatt and burthensome," each carrying down 4, 5, or 6,000 Bengal maunds of 82 Ibs. Each".[469]

From the 1740s silk prices rose steadily higher at Kasimbazar and alternative sources of taxation had to be found.[470] Therefore the saltpeter trade was promoted almost as a royal monopoly at first and then through revenue framing. The English records tell us that Umichand, a merchant-courtier with close links to the court at Murshidabad, was one of the monopolists in the trade of saltpeter from Bihar in the eighteenth century. His brother, Deepchand was the faujdar of Chhapra in Bihar, and the major part of Bihar saltpeter came from there. Umichand and Deepchand were courtiers and royal favourites, linked both with the nawab Alivardi Khan and his brother Haji Ahmad who managed the royal commercial interests in Bihar.

Saltpeter concessions were sold off to courtiers by the nawabs. The Armenians monopolized a large part of the saltpeter

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467 Chandra Richard de Silva, 'The Portuguese East India Company 1628-1633', *Luso-Brazilian Review,* Vol. 11, No. 2. (Winter, 1974), pp. 152-205. See pp. 187-88.
468 Kumkum Chatterjee, pp. 26-28.
469 Bowrey, pp. 225-29.
470 Mukherjee, 2006a.

trade from Bihar in that century, as we saw from Khwaja Wajid's career. As part of a social-commercial-political network (Umichand, Deepchand, Khwaja Wajid) with direct access to the courts at Murshidabad and Patna, Khwaja Wajid virtually monopolized the Bihar trade, particularly in saltpeter, from the 1740s, through an annual payment of Rs. 25 000 to the nawab Alivardi Khan.[471]

A Dual Shift? The Case for Opium?

While Bowrey referred to the trade in saltpeter, De Graaf referred, at the same time as Bowrey, to the great production and trade of opium; one maund of opium in Bengal costing Rs. 70 or 75 was sold at Batavia at between Rs. 210 and 225, adding however, regretfully, that this profitable trade was not open to the Dutch.[472] Luillier echoed this at the start of the eighteenth century, nothing that there was great trade in opium, it being much in demand in the Levant,[473] adding that 'on peut dire que Bengale est le magasin de toutes les Indes'.[474] Luillier too claimed that the East India companies were denied participation in this trade.

Who, then, organized this trade? Was the opium trade also in the hands of 'up country' merchants? In seventeenth century Achin merchants from Bengal brought raw cotton, textiles, ghi (clarified butter used as oil in cooking) and opium into that port.[475] Until the middle of the eighteenth century, both the opium and saltpeter trades functioned as almost "royal" monopolies. The

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471   Sushil Chaudhury, 2005, p. 56.
472   de Graaf, pp. 307-08.
473   Luillier, *Voyage du sieur Luillier aux Grandes Indes, avec une instruction pour le commerce des Indes orientales,* (Paris, Claude Cellier, 1705) p. 79.
474   Luillier, p. 69.
475   In Denys Lombard, *Le Sultanat d'Atjeh au temps d'Iskandar Muda 1607-1636*, (Paris, EFEO, vol. LXI, 1967) p. 116.

Armenian Khwaja Wajid was active in this trade too, acting almost as monopolist; he was reported to have cornered the market in Bihar opium in 1749.[476]

Salt

Salt became an increasingly lucrative commodity in eighteenth century Bengal. We read that this salt came down from Agra. But salt was also obtained from far. We saw that Teixeira wrote circa 1600 that ships from Cochin arrived at Hormuz to pick up salt destined for Bengal, where this salt was much prized as Bengal, apart from the island of Sandwip, suffered from a scarcity of salt.[477]

Khwaja Wajid obtained the more lucrative monopoly of the salt trade which was farmed by him in 1752 for a mere payment of Rs 25,000 to Rs 30,000 a year to the nawab. An estimate of 1773 put the annual revenues of salt production and sale in Bengal at Rs 1 million. It is thus apparent how much Khwaja Wajid earned from the virtual monopoly of salt trade in the 1750s.[478]

New Commodities at the Mid Century Break

We see that the Bengal nawabs experimented with a portfolio of export commodities in response to foreign demand. The traditional exports of rice, sugar and cotton were supplemented with, and then supplanted by, silk, saltpeter, opium and salt. From

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476   Sushil Chaudhury, 2005, p. 57.
477   W.F. Sinclair and D. W. Ferguson eds. *The Travels of Pedro Texeira* etc., (London, Hakluyt Society, Second Series, 1902).
478   Orme Mss OV 134, ff. 21-2 in Sushil Chaudhury, 2005, p. 57.

1711 the English East India Company's investment in saltpeter was immense.[479] By 1718 the English East India Company's factory in Bihar was contracting 10 000 maunds for the Madras factory as well.[480]

The process underlined in this paper, from simpler and looser networks, based on considerable religious and ethnic diversity, and concentrating on a portfolio of commodities, toward more complex networks based on single items, was the hallmark of the age. He Armenians typify the former kind of network. The East India companies moved from simple networks toward more complex networks from the end of the seventeenth century, and the nawabi state of Bengal emulated this process by way of experimenting with single items such as silk, saltpeter, opium and salt. But it was too late. Thus attempts at royal monopolies in saltpeter, opium and salt around the middle of the eighteenth century failed and could not survive the mid century break. This was mainly due to the new and complex financial and organizational networks set in train by the European companies.

Conclusion

In 1757 Kasimbazar, and Bengal, was conquered by the English East India Company, and the occupation of Bengal laid the ground for the future colonization of India. Having seen the flourishing state of commercial networks in Kasimbazar, we can ask ourselves this question: were the networks for these newer commodities more robust, more complex and more controlled

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479   C.R.Wilson, V.1, pp. xxii, lviii, lix, 15, 29, 141.
480   C.R.Wilson, V.1, p. 305.

by outsiders, and is that why the Bengal economy became more vulnerable to a takeover by outsiders?

But how successful could the new networks be if they remained confined, on the ground, within the older specializations and knowledge that we referred to at the beginning? New techniques, and consequently new networks, could never be completely successful unless and until they destroyed older systems of knowledge. The case of Piedmontese silk reeling technology, introduced under the aegis of the English company, was never successfully adopted by the Bengali peasants involved in reeling silk.[481]

In sum, we may argue that neither strategy was successful. The older, simple networks failed to coalesce into more complex and robust networks and hence indigenous commercial initiative declined. But the more complex networks of the European companies also failed to root themselves and this is why they concentrated increasingly, from the end of the eighteenth century, on Calcutta and a portfolio of completely different commodities. Kasimbazar became a backwoods.

This malign swing in Kasimbazar's trading networks was reflective of another shift, one perhaps little understood at the time. This shift took place within northwest Europe and spread over the Indian Ocean. From the seventeenth century European merchants were present in Asian waters, either as individual traders or as traders under a national flag. Here they collaborated with Asian merchants (for example. the Armenians who, represented by Khoja Panos Calendar in London, signed in 1688 the Treaty of East India

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481   Roberto Davini, 'Bengali raw silk, the East India Company and the European global market, 1770– 1833', *Journal of Global History* (2009) 4, pp. 57–79.

Company with the Armenian Nation for cooperation in maritime commerce), and Asian states and gradually inserted themselves into maritime routes and financial and commercial networks. Kasimbazar was full of various networks of financiers and traders by the eighteenth century, its growth as urban centre was fuelled by two geographic networks that initially collaborated with each other, one Asian, the other European. Kasimbazar was born through Asian demand, as discussed here, but reinvented in the eighteenth century through European maritime demand, as the Kasimbazar Factory Records tell us. I would like to underline that the networks I dub here as "Asian" and "European" were never "formally" so, nor were they single networks, the terms "Asian" and "European" refer merely to the dominant geographical features of each network.

In the eighteenth century this cooperative model was gradually abandoned in favour of a more dominant model. The world of Kasimbazar, in transition in the seventeenth century, was integrated into global networks that spanned Europe, Africa and Asia, thereby transcending its earlier networks. The Armenians too were progressively marginalized by the English East India Company despite their treaty. The new networks were increasingly governed by financial and political power emanating from Western Europe. The economy at Kasimbazar therefore showed the transformation of exchange patterns from an initial bottom-up trajectory to a top-down path.

We do not yet know what happened when these two types of networks met each other, but we do know that when they initially intersected there was a trade boom at Kasimbazar, visible from the end of the seventeenth century and very apparent in the

eighteenth century. Production rose to met increased demand, there was a greater amount of money in circulation and merchants made fortunes overnight. This period of expansion ended from the 1730s, as reflected in the data from Kasimbazar, and the system entered into a period of crisis.[482] Between the 1740s and the 1750s the various components in the system started tumbling down, this translated into a cascading crisis. The crisis was visible in a price rise of silks and silk-cotton mixes, late deliveries, inferior quality, deviation from the samples shown, subsequent imprisonment of *dadni* merchants for non payments of dues, complaints to the nawab's court at Murshidabad, increasing impotence of the nawab in face of the growing power of the English East India Company and, ultimately, the bankruptcy of the *dadni* merchants at Kasimbazar.[483]

More significantly for our purposes here, it seems that the English East India Company demand had diverted production not only from the home (Asian) market but also from other European markets; witness the French East India Company's plea that fine quality *baftas* destined for royalty in Asia and in demand in France were no longer manufactured by the weavers at Jugdia because the English East India Company only wanted medium quality or coarse *baftas*.[484] Even more significantly, the old unitary production model was breaking down; earlier cloths were spun, woven and washed (to ensure the quality of the dye) in one place. The Bengal merchants had total control over the production process as well as choice of place to carry on production; moreover the price asked reflected this concentration of production in the hands of the merchants.

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482   Mukherjee, 2006a.
483   See Ibid.
484   Ibid.

Now, due to company exigencies of timely deliveries (to meet shipping schedules) and the worry of additional financial charges due to late deliveries (much like credit card charges in our world!), cloths were transported to be washed at the various regional East India Company HQs; either because the ponds at the production points were polluted or because the deliveries were late, thereby forcing the ships already waiting at the regional harbours to depart for their outward journeys without their consignment if the cloths were not delivered "finished" within a certain period.[485] New productive nodes were thus created due to the failure of older networks.

By the late 1760s the foundations of the early colonial economy were taking shape, underlining the phase transition to the colonial economy of the nineteenth century. Transport routes were breaking down, there was decline in law and order, large numbers were dying from famine and lawlessness, and the European investments could not be procured in either Bengal or Bihar.[486] It was precisely at this time that the English East India Company and the French East India Company sought to bypass "interference" at the older Mughal mart towns and set up new market towns elsewhere. Here they attempted to draw buyers and sellers and thereby denied the Mughal order the customs and transit duties due to it.

So the new networks were clearly visible by the 1770s. Additionally, in 1770, a terrible famine ravaged Bengal and Bihar, caused by the reckless revenue farming policy adopted by the

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English East India Company once it gained control over Bengal's revenues in 1765. Mughal poets, scholars and philosophers in Kasimbazar, Patna and Calcutta started lamenting the alien regime of the "hat wearers"; they spoke of a revolution *(inquilab)* and remembered fondly an earlier golden age.[487] The phase transition must have been brutal.

Of particular note here are two events that moulded the peculiar conditions of the time: the terrible Bengal famine of 1770 which signaled the role of European capital and English East India Company greed in the breakdown of the old order, and the Permanent Settlement of the Bengal revenues by Cornwallis in 1792 which signaled the demise of the old and the passage to the new. Both saw the end of the old social networks that we study here. The old silver and gold standard now yielded way to paper money printed by the English East India Company. The old financial order too was now defunct. Financial networks had already passed into oblivion.

Maps are from Frances Pritchett's remarkable collection hosted at: http://www.columbia.edu/itc/mealac/pritchett/00maplinks/index.html#index accessed 21-04-09.

They are used here with her kind permission.

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487   Anand Yang, *Bazaar India: Markets, Society and the Colonial State in Bihar*, (Berkeley and Los Angeles, California Press, 1988).

Map 1: Kasimbazar in Empire de Mogol in Robert Morden, A Description
of the World, London, 1688

Here is one of the earliest maps showing Kasimbazar
("Casanbazar"). It is important enough to be shown on a map of
the world but is wrongly placed near the Orissa coast, just above
"Ouguli" (Hugli); in actual fact it is situated further to the north of
Bengal, near to where "Gouro" is marked.
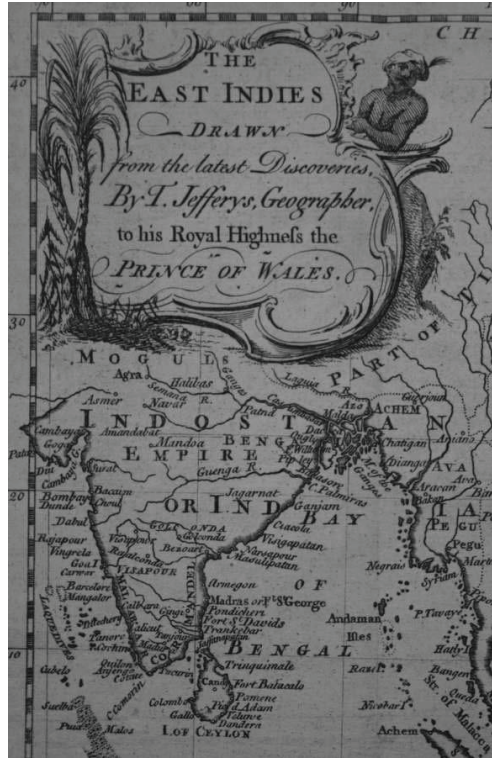
Map 2: Kasimbazar in the "royal" East Indies by Thomas Jefferys, London, 1748

In this particular map Kasimbazar's links with the delta are emphasized.
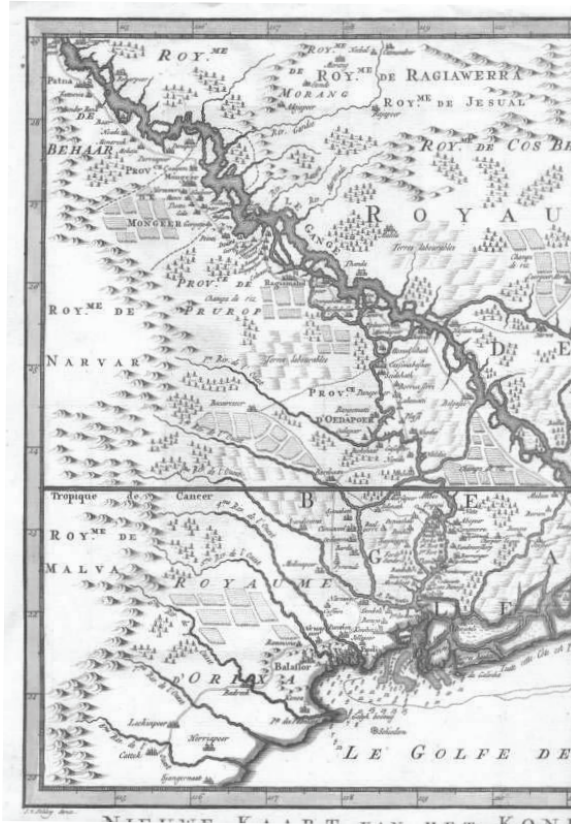
Map 3: Kasimbazar in the urban and commercial networks of Bengal

From Jacques Nicholas Bellin, From Nouvelle Carte du Royaume de Bengale (1747-61), first issued in Prevost's *Histoire Generale des Voyages*, Amsterdam/Leipzig, circa 1750.

This is a beautifully detailed map. See the urban and fluvial networks of Kasimbazar, lying roughly to the middle here, as also the intensely cultivated area it is centred on.

Map 4

Rigoberto Bonne's map of India, 1780, showing the Position of Kasimbazar within the northeastern part of the sub continent.

From Rigoberto Bonne, "Carte de la Partie Superieure de l'Inde en Deca du Gange Comprise entre la Cote du Concan et celle d'Orixa, avec l'Empire du Mogol, le Bengale etc." in Guillaume Reynal's *Atlas de toutes les parties connues du globe terrestre*, published in 1780.

Note the fluvial gateway to the north of India, as also Kasimbazar's (here as "Casimbazar") southward links to the delta. The ports of Calcutta (EEIC) and Chandernagore (FEIC) are marked, Chandernagore somewhat more prominently that Calcutta, not surprising given the nationality of the cartographer. Interestingly, the Dutch port of Chinsura (Chunchura) is not marked on this map, nor is Serampore (Srirampur), the port and settlement of the Danish company, marked. Not surprisingly, Bankibazar of the Ostend Company (Belgium) is ignored; as it hardly functioned as port and factory by that time.

Map 5

Rennell's Map of Inland Navigation of Bengal from Bengal Atlas, London, 1779-83, taken from Jean Deloche, 'Boats and Ships in Bengal Terracotta Arts', *Bulletin de l'Ecole Française d'Extrême-Orient*, 1991, 78, 1, pp.1-49, p. 4.

Integration of Virtual Map Rooms as a support tool in historical and social research[488]

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Miguel Ángel Bernabé Poveda Alberto Fernández-Wyttenbach
(Universidad Politécnica de Madrid, Spain)

Introduction

At the present time almost all map libraries on the Internet are image collections generated by the digitization of early maps. This type of graphics files provides researchers with the possibility of accessing and visualizing historical cartographic information keeping in mind that this information has a degree of quality that depends upon elements such as the accuracy of the digitization process and proprietary constraints (e.g. visualization, resolution downloading options, copyright, use constraints).

In most cases, access to these map libraries is useful only as a first approach and it is not possible to use those maps for scientific work due to the sparse tools available to measure,

match, analyze and/or combine those resources with different kinds of cartography.[489] Two such online sources are *The American Geographical Society Library Digital Map Collection*[490] (containing over 500 maps ranging from early maps of Asia to historical maps of Wisconsin and Milwaukee) and the LUNA Browser[491] of the *David Rumsay Map Collection* (which currently contains over 22.000 items online, mainly rare 18th and 19th century maps of North and South America as well as other cartographic materials). These collections allow the user to access and query certain characteristics but they do not provide tools to analyze the maps, much less integrate them in a geographical context. Another relevant online historical content provider is *The World Digital Library*.[492] The WDL makes it possible to discover, study, and enjoy cultural treasures from around the world on a single website. Its cultural treasures include but are not limited to maps. Nevertheless, WDL is once again an interesting data repository in which the opportunity to provide geographic tools was not taken.

More recent applications provide the geographical context but there are not enough tools for getting the most from the maps. A first approach was the Google Maps Rumsey Historical Maps[493] portal of the *David Rumsey Historical Maps* collection. These new

489   Fernández-Wyttenbach, A., Siabato, W., Bernabé-Poveda, M.A., Wachowicz, M.: "Evolution of Digital Map Libraries towards Virtual Map Rooms: new challenges for the historical research", In: *Mapping Different Geographies*, Kriz, K. and Cartwright, W. et al. (Ed. Heidelberg-Germany: Springer Verlag, 2010)
490   The American Geographical Society Library: Digital Map Collection , University of Wisconsin (27/05/2009) <http://www.uwm.edu/Library/digilib/maps/index.html> [04/03/2010].
491   David Rumsey: *David Rumsey Map Collection*, Cartography Associates (21/01/2010) <http://www.davidrumsey.com/view/luna> [23/03/2010].
492   U.S. Libraryof Congress and UNESCO: *The World Digital Library* (WDL) , UNESCO (11/03/2010) <http://www.wdl.org/en/> [23/03/2010].
493   David Rumsey: *David Rumsey Historical Map Collection* , GeoGarage (29/05/2008) <http://rumsey.geogarage.com/> [23/03/2010].

interfaces (Google Maps and Google Earth) allow visualizing the early maps on Google´s globe. This way, it is possible to visualize them georeferenced and to compare them with contemporaneous cartography. One hundred and twenty historical maps have been selected by David Rumsey from his collection of more than 150.000 historical maps to be shown on the Google viewers. This small sample is a good example of how geographic environments can be used for sharing early maps.

One step ahead is The Alexandria Digital Library geographical browser[494]. This interesting geographic approach provides tools for discovering and accessing maps. It offers a rich interface for querying the resources providing up to four different panels of search parameters. The main difference between Alexandria's interface and the Rumsey approach is that the first one comprises a single interface for accessing any map from the collections and it is possible to see more than one resource at the same time. This service is also based on Google Maps in order to provide the geographical context. A comprehensive description of the evolution of Digital Map Libraries (DML) and the most relevant online services, stressing the challenges in the design of the next generation of Virtual Map Rooms, is available in *Evolution of Digital Map Libraries towards Virtual Map Rooms*: new challenges for the historical research492.

But while the Web mapping/visualization tools developed by Google and Microsoft provide very fast, easy-to-access views of images and maps, they are not suited for complex work and analyzes. However, the pervasive use of these new environments

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494   The Alexandria Digital Library: *Globetrotter - NGDA Interface* , University of California (16/05/2009) <http://clients.alexandria.ucsb.edu/globetrotter/> [23/03/2010]

offers an opportunity for sharing data and specifically early maps. So, it is evident that it is essential provide users with environments like these but offering enough tools and elements for using early maps properly, not just for seeing them.

Therefore, setting up robust Virtual Map Rooms (VMR) as a tool for supporting historical projects, in which a large number of national and international researches and institutions are involved, means an advance towards avoid the lack of applications that could provide historians and documentary experts with remote access to the existing information from any map library around the world, and also with a set of tools for exploiting and analyzing them. As Dangermond asserted[495], Web-based mapping have been very important and now we are moving from simple mapping and geospatial visualization to full online geoservices. This allows extensive sharing of maps and maps and opens up access to geographic applications to everyone. This, together with the growing availability of georeferenced content and the ability to easily search, discover, and mash up these service, is enabling a whole new pattern and architecture for geographical applications. This pattern emphasizes open and interoperable services that can be used to support a broad array of geographically related applications such as the proposed Virtual Map Rooms. Because of that and following the evolution of the geographic services on the Web, the VMR and tools will be available through one single and usable portal on the Internet.

The proposed VMR facilitates access to digitized resources (restricted and unrestricted) and working with maps located in dif-

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495   Dangermond, J.: *GIS and the GeoWeb, ArcNews*, Num.30 ESRI (Summer 2008) 1/21

ferent map libraries all over the world. It also provides a set of tools implemented for the geographical treatment and manipulation of these resources. In addition it simplifies the task of the institutions which are in charge of preserving those archives: optimising human resources, guarding against misappropriations and avoiding direct manipulation of those archives being in a fragile conservation state.

This job is at the same time an instance of how the Geographic Information Technologies may be useful for the professional and research work of historians and social scientists in general, remarkably contributing to the dissemination of the History of Cartography and Cartographic Heritage in the most specialised academic environments.

The paper is structured as follows; part two presents the research context of the project and how a VMR could be useful for historians and researchers in general. Part three describes the implementation of the Virtual Map Room: shows concepts about the data repository, the architecture of the service, the data server and the implementation of a Web client. Part four presents an enriched graphic user interface that contains new tools for interacting with the data repository and maps, including a querying-timeline component for accessing maps easily. Finally, conclusions are presented, and further steps to strengthen the platform implementing other services are discussed.

Research context

It is possible to state that Spatial Data Infrastructures (SDI) are by now a methodological and technological benchmark for publication of the cartographic heritage.[496] The use of the standards

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496   Fernández-Wyttenbach, A., Álvarez, M., Bernabé-Poveda, M., Borbinha, J.: Digital Map

and recommendations defined by the Open Geospatial Consortium (OGC) enable accessing to historical-cartographic information with a degree of detail only restricted by the quality of the digitalized documents and associated information issued by each supplier institution.

Thus we underline the high potential of map servers consistent with the OpenGIS standards and specifications, specially *OGC Web Map Service Interface Standard (WMS)*[497], and its capability to set up a platform enabling distributed access to different historical archives. Despite this, it is necessary to be able to find the way for creating and providing the most appropriate virtual tools in order to undertake the usual studies that are being carried out on the old maps by librarians or researchers, either intrinsically on the document or in relation to the real world. This way, metric tools will be available to find out real distances and surfaces among other characteristics and also to make possible analysis that researchers can formulate on the maps (georeferenced documents). In addition to the conventional GIS tools, new ones have been developed to facilitate access to data repositories and manipulation of the results of the queries.

From the beginning it was observed that the appropriate scenario for development and integration of a virtual map room would be within the context of a historical social research project and better if this project would have had international repercussion. Such is the case of the DynCoopNet Project in whose case the need to rely on distributed access of the diverse cartographic archives

Libraries Services in the Spatial Data Infrastructure (SDI) Framework: The Digmap Project. In: *23rd International Conference in Cartography. International Cartographic Association*, Moscow (2007)

497   Open Geospatial Consortium: *OpenGIS® Web Map Server Implementation Specification* 1.3.0, (OGC® 06-042) (J. d. Beaujardiere), OpenGIS® Implementation Specification. Open Geospatial Consortium. (2006)

was recognised.

The aim of DynCoopNet is to provide new theoretical insights about the dynamics of complex systems (the evolution of cooperation tying together the self-organizing commercial networks of the first global age) through the implementation of GIS as data integration engine, fed by distributed databases which store large data sets and information collections, and by using tools for management and discovery of information and tools for temporal analysis and visualization.

It is advisable to develop and setup a Virtual Map Room (VMR) based on open standards and taking into account the mentioned above tools. This VMR will enable historians and researchers from DynCoopNet and other projects to access to the huge amount of information which encompasses the First Global Age and/or any kind of data collections that are available to be shared. Figure 1 shows a snapshot of the proposed VMR.
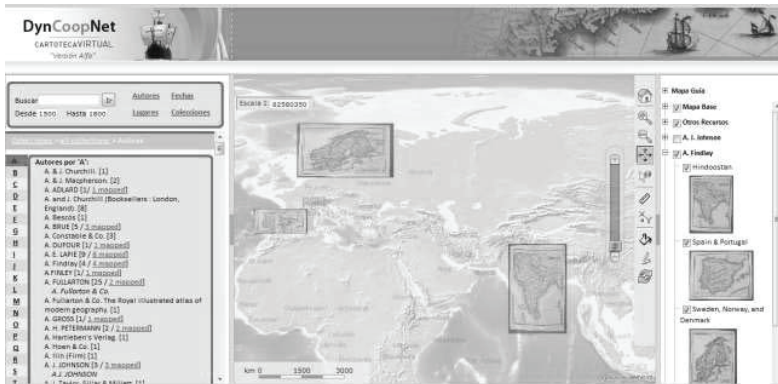

Figure 1. Virtual Map Room of the First Global Age (http://www.dyncoopnet.
eu/cartoteca)

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Implementation of a Virtual Map Room

The Virtual Map Room has been implemented as a network of cooperating physical servers, providing services, and data via these services. This permits savings in development time, operating costs, and allows for uniformity of data supplier and resources. The organizational structure, operating environment, technical arguments and technological components of this proposal, including the relationships between its parts, and the principles and guidelines, entirely belongs to a typical Spatial Data Infrastructure architecture. This principles are enough robust and mature for sharing any kind of geographic data.

In order to achieve the integration of map libraries and its resources and archives, the team project has setup a virtual space based on Web servers, map servers, CGI and PHP/MapScript support, AJAX support, and other technical elements which provide enough tools and services to offer a rich, robust and reliable VMR. These components have been selected as part of the SDI architecture. The main element is the map server, through which the publishing of geographic and spatial data is feasible. This map server has been recompiled for fulfilling the requirements of researchers, fine tuning the service, and improves performance of OGC specifications.

On the other hand, it has also been designed a specific Web client for enabling access to the DIGMAP[498] search engine and to the old cartography repository. This Web client, which is a online interface, synchronises the search engine with a geographic

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498   DIGMAP: *Discovering our Past World with Digitised Maps* (Programme eContentplus – Project: ECP- 2005-CULT-038042) (16 /10/2009) <http://www.digmap.eu> [23/03/2010]

browser that allows carrying out geographic browsing and querying operations once the searching process has been done.

The software platform of the project is based on Open Source projects both in the server and client side; most of them using the GNU General Public License which allows to use, change and share the software and secondary applications without restrictions and making sure it remains free software for all its users. This means the proposed framework is also under the GNU GPL.

Historical data repository

The information used in the test and implementation processes has been provided by DIGMAP - an online repository of historical-cartographic documents. This portal is the outcome of a European project co-funded by the Community programme eContentplus and published on November 2008.[499] The aim of DIGMAP was to turn its portal into the international reference gateway to old maps and related bibliography. The project proposed the development of solutions for digital libraries especially focused on cartography that promotes the cultural and scientific heritage.[500]

This project provides easy access to the thousands of early maps of national libraries and collections around the world through the Internet. This possibility is undoubtedly useful for the creation of a virtual map room that aims to provide information for historical and social research interests, since it allows massive

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499   DIGMAP: Discovering our Past World with Digitised Maps (Programme eContentplus – Project: ECP- 2005-CULT-038042) (16 /10/2009) <http://www.digmap.eu> [23/03/2010]
500   Borbinha, J., Pedrosa, G., Gil, J., Martins, B., Freire, N., Dobreva, M., Fernández-Wyttenbach, A.: Digital Libraries and Digitised Maps: An Early Overview of the DIGMAP Project. In: *Asian Digital Libraries:Looking Back 10 Years and Forging New Frontiers. LNCS,* vol. 4822, Goh, D.H.L., Cao, T.H., Sølvberg, I., Rasmussen, E. (Ed.) pp. 383-6. (Springer, 2007)

access to a huge amount of cartographic information and related documents, no matter where it is stored. The main service is a specialised digital library which recovers metadata from European national libraries and offers online map searching and access to the contents. Metadata from other sources are also reused as well as descriptions and references to other relevant external resources[501/502]

It is important to stress that DIGMAP is a virtual digital library, in the sense that it holds only the metadata that describes the resources, but not the resources themselves, what remain in the local libraries or Web sites (It means that the VMR access the original resources through these metadata). The resources also can be (i) digital-born, (ii) digitized, or even (iii) physical resources existing only in the shelves of the libraries. When the resources are digitized maps, it is possible to index them by their geographic boundaries.

Independent of its technical and technological contributions, this is the real added value of the DIGMAP Portal as data engine for the development of virtual map rooms, the large amount of digital maps that has previously been indexed and georeferenced. This characteristic allows to the geographic browser shows the map in the right position when the resource is queryable, in other words, when the resource is georeferenced, otherwise it won´t be possible to show the map on the geographic browser.

501   Pedrosa, G., Luzio, J., Manguinhas, H., Martins, B., Borbinha, J.: DIGMAP: A Digital Library Reusing Metadata of Old Maps and Enriching It with Geographic Information. In: *Research and Advanced Technology for Digital Libraries. LNCS*, vol. 5173, Christensen-Dalsgaard, B., Castelli, D., Ammitzboll Jurik, B., Lippincott, J. (Ed.) pp. 434-5. (Springer, 2008)
502   Martins, B., Manguinhas, H., Borbinha, J., Siabato, W.: A geo-temporal information extraction service for processing descriptive metadata in digital libraries. In: *e-Perimetron. International Web Journal on Sciences and Technologies Affined to History Of Cartography,* vol. 4, no. 1, pp. 25-37. (Thessalonica, 2009)

Figure 2 shows the georeferencing process in the *DIGMAP Geographic Index module.* It should be noted that the geographic referencing process in DIGMAP is not high-accurate and it just supplies an approximate location of the maps based on the maximum and minimum coordinates of a bounding box. This reduces the accuracy of measurements and operations on the map. Nonetheless it is valid enough as a first approximation. There are methods that deal with the geometric and projective characteristics and properties of early cartographic representations[503/504] that could be taken into account in the future in order to improve this weakness for online resources.
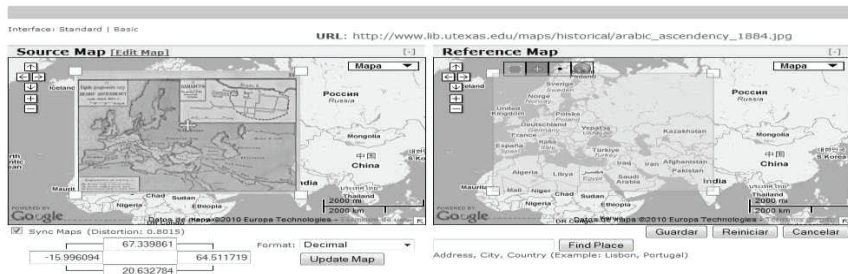

Figure 2. Geographical indexing of historical contents in DIGMAP

However, the geographic browsing tools associated to the DIGMAP search engine are excessively simple and do not follow the appropriate usability criteria.[505] For this reason, it is necessary to

503   Livieratos, E.: On the Study of the Geometric Properties of Historical Cartographic Representations. In: *Cartographica*, vol. 41,no. 2, pp. 165-75. (2006)
504   Boutoura C., Livieratos. E.: Some fundamentals for the study of the geometry of early maps by comparative methods. In: *e-Perimetron. International Web Journal on Sciences and Technologies Affined to History Of Cartography*, vol. 1, no. 1, pp. 60-70. (Thessalonica, 2006)
505   Fernández-Wyttenbach, A., Moya-Honduvilla, J., Álvarez, M., Bernabé-Poveda, M.: First approaches to the usability of Digital Map Libraries. In: *e-Perimetron: International Web Journal on Sciences and Technologies Affined to History Of Cartography,* vol. 3, no. 2, pp. 63-76. (Thessalonica, 2009)

develop a new interface that allows researchers to access this huge collection easier than now and use the maps in a better way.

So that this interface could be really useful and assure system interoperability, it has been chosen to incorporate to the virtual map room the basic concepts of the SDI reference framework. Thus the results (maps and documents) are presented on a web-mapping framework in accordance with the usual OGC services, providing cartographic information using independent layers, assuring process and platform compatibility, and therefore, making easier the documentary research for librarians, historians and other researchers. The next sections describe the server and client processes.

Figure 3. Synchronisation of results combined with the transparency function

Geographic data server

After having identified the characteristics of the data repository, and knowing the benefits and disadvantages of

geographic servers available currently on the market[506/507/508], the geographic data server MapServer (http://mapserver.org) has been chosen as the most appropriate option for management and publishing of cartographic and historical information. This server offers enough quality, reliability and functionality for sharing data on the Internet. It supports display and querying of hundreds of cartographic data sources and formats, rendering and showing them using different reference systems and projections through the on-the-fly projection capabilities. In addition, it assures high quality rendering. These characteristics are very useful for the integration of early maps, WMS data layers and other cartographic resources. For instance, transparency and antialiasing properties are quite efficient for showing early cartography on a reference WMS layer as shown in Figure 3.

MapServer is a general platform for publishing spatial data and other geographic applications to the Web. Based on the language ANSI C/C++, it may be executed, configured and customised in a large number of operative systems and environments. This means that the framework developed on this proposal can run almost on any platform configuration of any map library. Also, MapServer holds external libraries allowing its extensibility and supports many raster, vector and database formats. This characteristic proves essential when accessing, extracting and serving data from different historical data repositories, such as the ones described above in the DIGMAP Project.

506   Jansen, M. 2009, 'Comparing apples and oranges: Uncovering the mystery of component selection in WebGIS projects', in *FOSS4G 2009*, Sidney - Australia.
507   Aime, A. & McKenna, J. 2009, 'Web Mapping Performance Shoot-out', in *FOSS4G 2009*, Sidney - Australia.
508   Aime, A. 2009, 'GeoServer in Production', in *FOSS4G 2009*, Sidney - Australia.

The flexibility of using that the server offers through the exchange of parameters using conventional HTTP request methods, GET and POST, allows to dynamically configure the appropriate variables to meet the specific needs of a particular user at a given instant. It thus solves the drawback of generating maps using a static configuration file which does not allow modifications by external users. Due to the development characteristics of the DIGMAP components in which the message interchange is handled through this technique, MapServer is a candidate that covers interaction with the historical contents of the map libraries and other future collections that someone wants to integrate.

This way and from a technical point of view, it is possible extract the information and visualizes it on the client by means of parameterized URL query strings. On one hand, the geoinformation is extracted from the historical documentation repositories to generate a raster file as a result, and on the other hand, a text file with additional information is also obtained for subsequent georeferencing process. The generated information is accessible from a temporal URL that points to a public directory of the Web server in which MapServer is executed as a Common Gateway Interface application (CGI). Thus, the server has available the image and the information required for georeferencing.

Once the access to the repository data has been solved and the platform has been defined, next step is to visualize the information and to offer users (librarians, historians, researchers) the necessary tools[509/510] to be able to interact with the identified

509   Saracevic, T.: 'Digital library evaluation: Toward evolution of concepts', In: *Library trends*, vol. 49, no. 2, pp. 350-69. (2000).
510   Marchionini, G., Plaisant, C., Komlodi, A.: The people in digital libraries: Multifaceted approaches to assessing needs and impact, In: *Digital library use: Social practice in design and evaluation*, A.

resources.

Service architecture scheme

The typical application flow for data services based on MapServer is diagrammed in Figure 4. The basic architecture of MapServer applications contains a MapFile, Geographic Data, HTML Pages, MapServer CGI application and the HTTP Server. The MapFile is a structured text configuration file that defines where the data is and where to output the generated images. It also defines map layers, including their data source, projections, and symbology. Through these elements we can define sources for early cartography and load them.

These sources define the second element of the basic architecture: Geographic Data. The geographic server supports several data input formats by default, but in our case we have compiled it with the open source libraries GDAL and OGR in order to get more formats and offer a higher quality images. For this service, we are using WMS layers, Shape File format and support for Alpha channel through AGG driver. This way, we ensure the application can read and load any file from any library or data source.

HTML Pages is probably the main element because it's the interface between the user and MapServer. This item is fully provided by the p.mapper framework, thus it's possible to focus only on the data and functionality. The MapServer CGI application and the HTTP Server are the core of the systems. The CGI is an

Bishop, N. van House , B. Buttenfield (Ed.). 119-60, MIT Press, (2003).

executable file that receives requests and returns images, data, and other elements which are used by the HTTP Server for serving up the html pages when the user (researchers) hits the browser. For this case, the VMR is supported by Apache 2 HTTP Server.
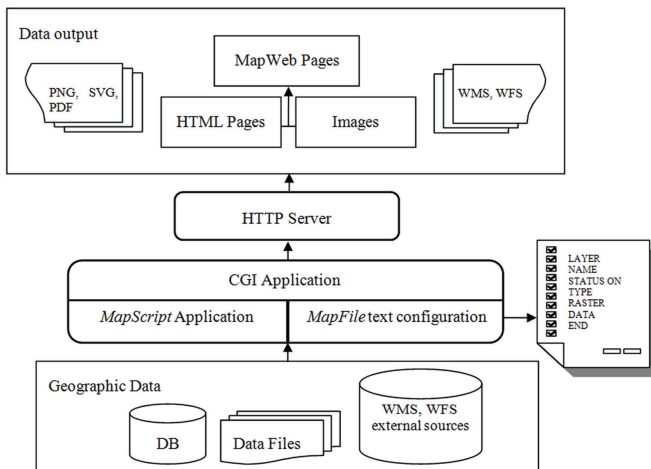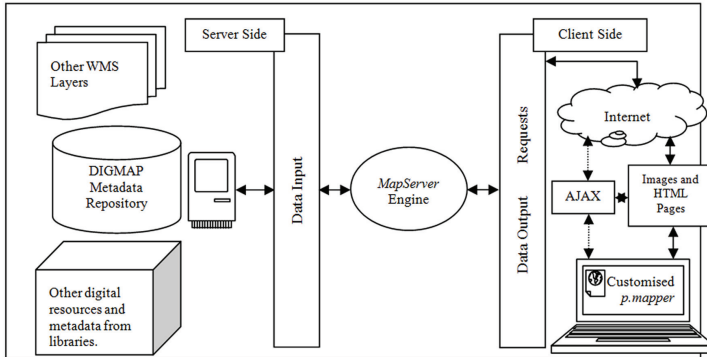

Figure 4. Typical application flow of MapServer

Based on Figure 4, it's quite easy to describe data flow of the VMR. In brief, MapServer gets the resources through the DIGMAP collection by URL requests, and displays them on the Web client (p.mapper).

The early cartography Web client

To interact with the queried resources it is necessary to rely on a stable and functional interface which suits for the purpose of a virtual map room. Taking into account that currently on the market there is a large supply of robust and high-performance thin-client web-mapping frameworks, it was decided to build our proposal based on these clients and not to develop a new one from scratch since most of them comply with the minimum historians' requirements[511] to interact with old cartography. Among the desirable selection criteria should be emphasized: software license, programming language, model and structure, ease of customisation, language used by the API or application interface, OGC services that supports, dependence on the map server, inclusion of metadata components, interoperability and usability of its tools and perhaps most relevant, an Open Source framework for its easy adaptability to specific needs.

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511   Crespo Sanz, A.: The atlas of El Escorial, a forgotten map, *Boletín de la Real Sociedad Geográfica* Num.CXLV Royal Geographical Society of Spain (2009) 117-142.

After having analyzed the available options, it was decided that the visualisation framework best fitting the specific needs of map libraries is p.mapper (http://www.pmapper.net). p.mapper is a thin Web client which offers wide range of functionality and multiple options for facilitating the configuration and installation of applications based on MapServer and PHP/MapScript. It works following the multi-layer model and the client-server architecture which suits perfectly for geospatial data visualisation and its manipulation through basic browsing and querying tools. As we said above, it is characterized by using the *GNU General Public Licence* which ensures being able to modify the application and redistribute it without restrictions. On the other hand, it relies on a modular programming structure favouring the development and incorporation of new functionalities or modification of the existing ones, according to requirements. In addition to the characteristics already mentioned, p.mapper is programmed under de object-oriented programming paradigm, so useful for increasing functionality without modify the original structure.

As a thin client, p.mapper takes advantage of the last advances in Web technologies such as AJAX, enabling transfer of data from client to server and return of results asynchronously, updating information for the client without having to reload the website. This functionality is exploited to achieve a more natural and intuitive interaction with early maps. In addition, p.mapper supports several relational DBMS and contains JavaScript libraries that facilitate the programmer's task when it needs to update functionalities or create new ones. It handles the light format for data interchange JSON that minimises the bandwidth expended in

client-server communications, with the consequent increment in response time and speed.

This way, we have used *MapServer and p.mapper* for providing access to historicalcartographic archives through a graphical Web interface. Linux Debian OS and the Web server Apache2 with the PHP5 as scripting language were used as server operating platform; on the client side, usual Web mechanism such as JavaScript (language script), Cascading Style Sheets (layout presentation) and XML (configuration) were used. As we said above, communication between server and client has been established through AJAX to provide natural interaction with maps. These tools allow any user access to data, regardless their choice of computer, software, browser or other specifications.

The results and performance obtained so far are reliable and the tests carried out indicate that this framework has been a good choice, especially for developing new specific tools for old cartography and integrating with the DIGMAP data repository.

Enriched graphic user interface

In order to offer historians and researchers an intuitive interface for accessing and querying maps; we have improved the client-framework developing new tools and functionalities. The framework has a flexible layout structure for including new elements into it through frame windows. There are some frames that remain empty, and which can be used for almost any task if the right techniques are applied. We have used these frames for including the DIGMAP engine and other external applications

that provide users with a single graphic interface for searching, querying and browsing data.

Due to the DIGMAP metadata repository had been already connected, it was necessary to synchronize both the data engine and the framework. This job was done using session variables. Through this method, we have achieved what we wanted to: incorporate metadata and data naturally so that user could manipulate them easily.

It is easy to check when the synchronization process has been done, once it has finished a new Table of Contents (TOC) is loaded in the browser. This new TOC shows the footprints of the available georeferenced sources, it must be kept in mind that not all the metadata records contain indexed geospatial sources. Figure 6 shows a customized TOC.
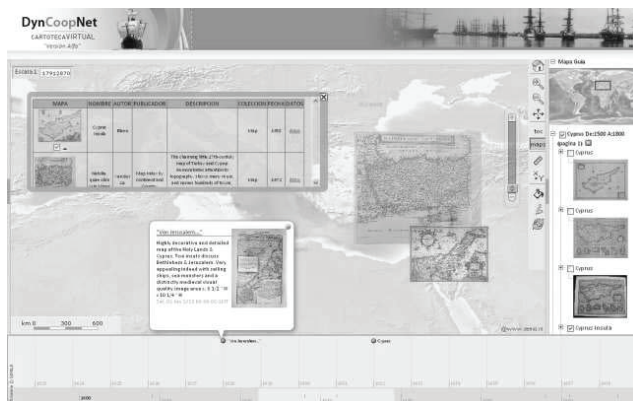

Figure 6. VMR customised functions for early cartography

Once the metadata have been loaded it is possible to describe the queried map. For this aim, there is a specific tool that loads and shows the information by clicking on the map. After this, a table describing maps is showed. This table contains a link to the original resource and a further description. Transparency properties are also been handled for this table in order not to vanish the geographic information. Finally, when user needs to change parameters or make new queries without taking into account the previous ones, it is possible to reset the client and delete the metadata and data previously loaded. A single gray X posted in the TOC will delete the current map.

Another useful tool is the incorporation of a temporal-line browsing synchronized with text searches on the catalogue and the geographic browser. This tool is based on The SIMILE© Project Timeline widget (http://www.simile-widgets.org/timeline). At the same way as we used an empty frame for including the DIGMAP engine, we have used a bottom-frame available in the p.mapper's layout. This tool is useful for knowing the main description of the map and better than this, to show an overall view of the maps in a single timeline. Through this tool, researchers will be able to query just the maps they really need independent of searching criteria locating them by date. It works as a complement for the searching that the user has previously done.

All these tools could be improved but offer a new way for interacting with early maps. Some new tools have been developed but it will be available at near-future. Next section describes some of these future tools and presents conclusions.

Conclusions and future advances

Virtual Map Rooms are tools of high interest for historical and social research projects. They provide specialised access to distributed cartographic collections and especially early maps collections. The success and sustainability of these tools will be influenced by their design and usability patterns; this shall be carried out according to the criteria of publishing of geographic information issued by SDI specifications. They are at the same time an instance of how the Geographic Information Technologies may be useful for the professional and research work of historians and social scientists in general, remarkably contributing to the dissemination of the History of Cartography and Cartographic Heritage in the most specialised academic environments.

This project has provided a Web-mapping application developed in order to supply valuable and comprehensive instruments for both representing and promoting the knowledge of cartographic heritage to a large number of people. As far as the application has been developed, the result is a web-mapping portal accessible directly from the Internet that makes historical-cartographic resources available for everybody. In this sense, some task for the internationalization of the project has been done but not enough for providing universal access. Some characteristics that cover this aspect will be included at near-future.

As a Web mapping platform, the VMR brings together the SDI Architecture into a single, easyto- use Web Portal that provides access to historical data repositories. Any data repository can be included in this portal; also any library which provides access to its digital contents through the DIGMAP Architecture will be part

of the proposed VMR automatically. It is the fastest way to provide access to the cartographic heritage on the web, leveraging the power of some of the best open source geospatial platform and the biggest repository of historic-cartographic data on the Internet.

Despite the existing proposals, the Virtual Map Room proposed on this paper is the biggest georeferenced historical-cartographic map collection on the Internet. This is due to the fact that the application uses the DIGMAP metadata repository, which provides access to over 2500 georeferenced historical maps. Unlike other collections that provide access to 150 georeferenced digital maps through *The David Rumsey Map Collection* and 300 in the case of The World Digital Library. In this sense, the VMR provides access up to eight times more than the other prestigious collections. However, it must be highlighted the quality of the maps. Although these collections offer few maps, they maintain a high degree of quality. Actually, the georeferencing process in these collections is a lot better than the one done in the DIGMAP engine, especially on the Rumsey collection.

If one compares digital access to georeferenced early maps, using web-mapping interfaces, will find that the tools available on the VMR are quite useful, intuitive and usable. The server has been setup for completeness, reliability and availability. The VRM relies on the SDI architecture foundations. This job has supplied a supported web mapping platform for larger configurations related with early cartography. Finally, we have added key components that simplify and enhance the user experience and support the work of libraries in charge of preserving cartographic archives.

This project will include at near-future some significant improvements into the Virtual Map Room by giving new technical

and conceptual contributions that will enhance its usability according to users' requirements. To that end, it is necessary to address the following issues:

(i) Incorporation of semantic and spatio-temporal components. These components play an important role to complement the research work carried out within the proposed platform. The presentation and implementation of them in a coordinated fashion will mean a considerable advance in the initial management of the information and will lead to a substantial change in the search habits that historians and researchers are used to.

(ii) Quality of the contents. It mustn't be lost sight of that the Virtual Map Room cannot be responsible for the quality of the information accessed. So it is not uncommon to find out that there are still collections without georeferenced archives or very poor descriptions (metadata). However it is important to highlight that the application is capable of automatically incorporating all the improvements that this contents can take in the future, as well as new catalogues or collections. It is necessary to incorporate tools that allow the user to check quality and reliability of the resources. Also, it would be useful to improve the georeferencing engine provided by DIGMAP.

Toward temporal annotation in GIS environments[512]

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Introduction

Almost from their outset, GIS have been used in different spatial areas of technical and scientific knowledge, including Humanities and Social Sciences, whose chief objectives are, among others, the representation and analysis of human events through time and space. However, for this it is necessary to develop the appropriate tools that allow historians visualising the geographical distribution of social networks on time-sensitive maps. Within this scope, linguistics has been of use both as a means and end in GIS applications since historical information lies to a large extent in natural language written texts. Utilisation of GIS for representation

of knowledge by making use of natural language narratives has been presented by Chin-lung Chang[513]; conceptualization of movement patterns derived from semantic modelling of natural language to confer dynamism to the GIS has also been investigated[514], as well as the visualization of historical narratives in semi-natural language.[515] However, the research carried out in the area of incorporation of historical corpora has been focused chiefly on the spatial component, not so much on the temporal component.

For this reason the main objective of this study is to increase GIS capabilities by incorporating the temporal component in order to obtain geographically integrated historical data through TimeML, so that they will be the basis for the dynamic representation within a GIS. This work is not meant to create new natural language processing techniques but it seeks to systematise the incorporation of the temporal expressions derived from a historical corpus, so that this new knowledge might be added to and analysed at the geodatabase, acting as a support for new applications dependent on temporal semantics. The DynCoopNet Project is framed within the study context of the cooperation between the commercial social networks set up during the 14th - 19th centuries. A large part of the available information is in the form of natural language written documents. Natural language information requires treatment for its subsequent representation and analysis in a GIS; hence there are certain limitations, among them the fact that the information

513   Chin-lung Chang, et al., "Narrative geospatial knowledge in ethnographies: representation and reasoning", (eds. K. Janowicz, M. Raubal and S. Levashkin. Berlin: Springer, 2009) 187–203.

514   Kathleen Stewart Hornsby and Naicong Li., "Conceptual framework for modeling dynamic paths from natural language expressions", *Transactions in GIS* 13(s1), 27–45 (2009).

515   Brian Farrimond et al., "Making History Happen: Spatiotemporal Data Visualization for Historians", (paper presented at Ems, second UKSIM European Symposium on Computer Modeling and Simulation, 424–429, 2008).

used by GIS to carry out analyses, to generate responses and represent them graphically must be previously structured. To the end of incorporating the information of the written texts of the time into a GIS and getting responses to the enquiries of historians about those historic events, a methodology has been designed for this purpose consisting of systematising and analysing these documents by means of temporal semantic annotation. In our study case we have chosen the commercial correspondence kept by the merchant Simon Ruiz in the 16th century, who might be considered an ensign of the Renaissance trade, whose routes and commercial agreements spread throughout the European continent and the new America. The letter selection is dated between 1567 and 1578 and it belongs to the Provincial Historical Archive of Valladolid which is made up of over 56,000 commercial letters. As mentioned above, TimeML[516] has been used on these texts for recognition and normalization of temporal expressions in old Spanish. In this paper the research work concerning the temporal component from the GIS and the NLP are presented first. Subsequently the markup language is described, and in the fourth section the methodology used in the identification and normalization of Spanish temporal expressions is exposed. Finally some conclusions are drawn and new advances and future work along this research line are pointed out.

Time: state of the art

Modelling time is a key topic for many researchers in geographic information science and in other fields. Spatio-temporal

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516   James Pustejovsky, "TimeML: Robust specification of event and temporal expressions in text", *Temporal and Event Information in Natural language Text. Language Resources and Evaluation*, 39(2-3): 123–164, (2005).

data modelling and representation is a widespread subject in the literature[517], yet there are certain limitations in design application. The two most common implementations are the versioning/time stamping model and the snapshot/time slice model, since they can be easily applied with the available software. In the case of the first model, time is an object attribute, and in the case of the second model, time is a space attribute. Other approaches such as the entity-relationship or object-oriented models add a temporal extension.[518] Although considerable brainstorming has come about on the building of designs, prototypes and storage of spatio-temporal data, no global model is yet to be found that could be used for any one application.[519] From the computational viewpoint, temporal information processing present in natural language texts has aroused great interest in the scientific community, as attested by the large number of workshops which have taken place in the area of creation of extraction and temporal analysis tools (TERQAS[520], TANGO[521], DAGSTUHL[522], MUC[523]); in the area of temporal semantic annotation languages (TIDES[524], TimeML[525]);

517   Monica Wachowicz and Jack Owens, "Space-time representations of complex networks: What is next?", *GeoFocus* (9), 1–8 (2009).

518   Frank Ostermann, "Modeling, Analyzing and Visualizing Human Space Appropriation", (PhD diss., Zürich, Switzerland, 2009) 18–36.

519   Michael F. Goodchild et al., "Towards a general theory of geographic representation in GIS", *International Journal of Geographical Information Science* 21(3), 239–260, (2007).

520   TERQAS: Time and Event Recognition for Question Answering Systems. ARDA Workshop, http://www.timeml.org/site/terqas/index.html (accessed February 26, 2010).

521   TANGO (TimeML Annotation Grafhical Organizer), http://www.timeml.org/site/tango/index.html (accessed February 26, 2010).

522   Dagstuhl Seminar Proceedings. Annotating, Extracting and Reasoning about Time and Events, http://drops.dagstuhl.de/opus/volltexte/2005/313/ (accessed February 26, 2010).

523   Advanced Research Projects Agency. Proceedings of the Sixth Message Understanding Conference (MUC-6) (1995). Software and Intelligent Systems Technology Office.

524   Lisa Ferro et al., "TIDES 2005, Standard for the Annotation of Temporal Expressions". T*echnical Report*, MITRE (2005).

525   op. cit.

in the area of annotation systems (TARSQI[526], TERSEO[527]) and in different evaluation workshops (TERN[528], TempEval[529]).

With regard to computational linguistics specifically, the automatic recognition of temporal information has been developed in recent years by the research group of the Brandeis University headed by James Pustejovsky with the creation of TimeML[530], a specification language for annotation of events and temporal expressions in texts. It has been recently adopted as an international cross-language standard (WD ISO 24617-1:2007) and it is compatible with ISO 8601 which specifies the standard notation to store dates. Modelling of temporal data from the natural language through TimeML will be used to structure, store and extract temporal information. Using semantics in GIS, spatial and spatio-temporal models oriented to movement, as expressed in natural language, have been created[531]; although most of these models use a specific domain ontology that serves as a data model.[532] Thus far the use of markup languages for modelling of natural language historical narratives is unknown, although there have been attempts in semi-

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526   Mark Verhagen et al., "Automating Temporal Annotation with TARSQI", (demo presented at ACL 2005, proceedings, 2005).
527   Estela Saquete et al., "Automatic resolution rule assignment to multilingual Temporal Expressions using annotated corpora", (paper presented at Thirteenth International Symposium on Temporal Representations and Reasoning, proceedings, 218–224, 2006).
528   DARPA TIDES (Translingual Information Detection, Extraction and Summarization). The TERN evaluation plan: Time Expression Recognition and Normalization. Working papers, TERN Evaluation Workshop (2004), http://timex2.mitre.org/tern.html (accessed February 26, 2010).
529   Mark Verhagen et al., "SemEval-2007. Task 15: TempEval Temporal Relation Identification", Proceedings of SemEval 2007, (paper presented at 4th International Workshop on Semantic Evaluation, ACL, Prague, 75–80, 2007), http://nlp.cs.swarthmore.edu/semeval/tasks/index.php (accessed February 26, 2010).
530   op. cit.
531   op. cit.
532   Guoray Cai, "Contextualization of geospatial database semantics for Human–GIS interaction", *Geoinformatica* 11(2), 217–237 (2007).

natural or adapted language. It has been argued in favour of the use of TimeML annotated corpora[533] for the subsequent realisation of analysis and complex visualisations of narratives. Texts documents do not have to suit a specific domain, but the information used may be of a different nature; for this reason we intend to develop a global model that might be used regardless of the text document type. In addition, we have taken into account the model standardisation so as to abide by the historians' querying requirements; thus all the model attributes have been registered.

Markup language TimeML

TimeML is a linguistic specification for events and temporal expression annotation that provides systematisation for extraction and representation of temporal information and for information interchange. The most characteristic properties of this language are: interpretation of temporal expressions, temporal annotation of events, and arrangement of events to others through a temporal anchorage. TimeML combines and extends characteristics of other temporal annotation standards such as STAG[534], a guide to annotate events and time in newspaper texts whose tag for temporal information is TIMEX; and TIDES[535], developed to mark temporal expressions of a document and identify their value (TIMEX2). In TimeML the temporal expressions are marked with the TIMEX3 tag, which purports to indicate an improvement with respect to

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533   Olga A. Kuchar et al., "Isn't It About Time?," *IEEE Computer Graphics and Applications*, vol. 26 (3), 80–83, (2006).

534   Andrea Setzer and Robert Gaizauskas, "Annotating Events and Temporal Information in Newswire Texts", (paper presented at LREC-2000, Proceedings, 1287–1294, 2000).

535   Ferro et al., 2005.

previous tags.

Other associated resources have been developed aligned to TimeML. TimeBank is a TimeML annotated corpus made up of 183 US press articles.[536] TARSQI is a set of tools for temporal extraction of information which includes temporal expression recognisers[537] and events.[538] The analysers of temporal relationships between events should also be mentioned.[539] The drawback is their still young course of development and the fact that all of them have been created for the English language.

TimeML: description and characteristics

This markup language has three basic tags: TIMEX3, EVENT, SIGNAL and three link subtypes: TLINK, ALINK and SLINK. Next a brief explanation of each tag is presented:

- TIMEX3 is used to mark temporal expressions: *21 st March 2010, yesterday, at 6 PM, next year*.

- EVENT is used to mark events mentioned in a text: *to occur, to believe, to study, to begin*.

- SIGNAL is used to annotate temporal signals: *before, after, during*.

- TLINK is used to mark temporal relationships: *Louise went to Madrid from the 1st to the 7th of February* (the temporal information is related to the event to go).

536   James Pustejovsky et al., "TimeBank 1.2", Linguistic Data Consortium, Philadelphia, PA. (2006).
537   Verhagen et al., 2005op. cit.
538   Roser Saurí et al., "Evita: A Robust Event Recognizer for QA Systems", (paper presented at *HLT/EMNLP 2005*, proceedings, 700–707, 2005).
539   Inderjeer Mani et al., "Three Approaches to Learning TLINKs in TimeML", *Technical Report* CS-07- 268, Computer Science Department, Brandeis University. Waltham, USA, (2007).

- ALINK is used to annotate aspectual relationships: *Mary will begin presentation of her paper at 12 noon* (the verb will begin is showing a phase of the event).

- SLINK is used to annotate relationships of modality or evidentiality: *John said he would go to Madrid in February* (conjeture is made previously the realisation of the event).

TimeML offers the possibility of expressing different granularities. It owns four types for time expression (TIMEX3):

- DATES is used for expressions referring to a calendar: *on the 22 nd of March 2010, last Sunday, yesterday.*

- DAY TIMES is used for a temporal expression less than a day: *this afternoon, at twenty minutes to three.* Attention should be paid to the distinction between these two types of times because of the different granularity of the expressions.

- DURATION is used to describe duration in time: *for four days, two years ago.*

- SET is used for expressions of repetition in time: *twice a week, every eight days.*

The referential temporal expressions are bound to the document date through an attribute called AnchorTime that enables establishing a temporal axis. Thus not only metadata and publishing date are used but also the temporal expressions of the entire document. These expressions extend queries not only to the publishing date but also to the time events occur, in which period of time, how long they last, etc. In the case of diffuse or vague expressions, the semantic limits would be determined by the duration of events through the TLINK tag, whose values are based on the 13 binary relationships of Allen's temporal algebra.[540]

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[540] James F, Allen, "Maintaining knowledge about temporal interval," *Communications of ACM,* 26, 11, 832–843 (1983).

Methodology

The purpose of our methodology is to analyse and systematise the texts making use of the temporal semantic annotation to incorporate these natural language expressions into a GIS.[541]

1. Linguistic processing of the corpus containing the tasks of tokenisation lemmatisation and *POS Tagging*.

2. Temporal expressions in historical corpus

3. Manual identification and normalisation of the temporal expressions with TimeML.

4. Towards creating tools for automatically extracting temporal information from text.

5. Incorporation of TimeML as part of a geodatabase

Corpus processing

The following process is proposed to extract the temporal information from the corpus:

1. Tokenisation: consists of breaking down a complex expression into simpler ones and work with them separately. The system should be able to partition expressions in words and sentences.

2. Lemmatisation: all the words belonging to the linguistic family of each lemma are built using the morphologic class to that effect.

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541   Marta Guerrero Nieto et al., "Incorporating TimeML into a GIS", (paper presented at *11th International Conference on Intelligent Text Processing and Computational Linguistics*, CICLing 2010, proceedings IJCLA, vol.1 (1-2), 269–283, 2010).

3. POS Tagging: this method tags morphologically and lexically every word of the text with the available information of a lexicon, a specific domain dictionary.

The automatic processor containing the described tasks is Tree Tagger.[542] The choice of this analyser has been due to the easy incorporation of new vocabulary within its lexicon. The difficulty regarding lemmatisation has to do with the procedure due to the specific characteristics of the texts (16th century Spanish): the lack of spelling normalisation, use of abbreviations and agglutinations, etc. renders necessary the semi-automatic lemmatisation. The POS Tagging has also been carried out semi-automatically since its lexicon is present-day Spanish. The Tree Tagger allows incorporating new lexicon manually. The semi-automatic procedure has been resorted to because this tool is unable to guess word tags not appearing in its lexicon.

Temporal expressions in historical corpus

The selected corpus is made up of 20 letters written in prose dealing with reciprocal trade between Simón Ruiz and his trade commissioner in Lisbon. The temporal characteristics of the text documents are:

a) They contain a rich, everyday vocabulary, such as "de pocos días a esta parte" (from a few days hither), *"diez del que viene" (tenth of next) or "a tantos días"* (within that many days). There may be different expressions with the same meaning: *"a muchos días"*

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542   Helmut Schmid, "Probabilistic Part-of-Speech Tagging Using Decission Trees", (paper presented at *International Conference on New Methods in Language Processing*, Proceedings, Manchester, UK, 44–49,1994).

or *"muchos días ha"* (many days ago).

b) Temporal expressions are classified into defined, referential and diffuse. Most of them are referential or deictic in the corpus, i.e. they refer to the narrative time in which the document is placed: *"ayer" (yesterday), "la semana pasada" (last week)*.

c) There are other incomplete, vague or diffuse temporal expressions: "algún día" (some day), "por muchos años" (for many years), and "los días pasados" (the past few days).

d) There are also expressions which may or may not have a temporal meaning depending on the context. Some of them contain the word *"tiempo" (time): "y en tiempo tanto estrecho" (and within such a limited period of time) meaning "at present", "at this time"; the word "ahora"(now): "no hay, por ahora, que entender en ello" (for the time being there is no need to know about it) meaning 'moment'; or the word "brevedad" (shortness, brevity): "que lo enbie con brevedad" (it should be sent as soon as possible).*

Although the markup language is standard, adjustment to old Spanish has been necessary since the collected temporal expressions offer unique characteristics in regard to structure and lexicon selection, i.e. it is necessary to determine the limits and characterization of the temporal expressions of the corpus.

Temporal annotation of the corpus

The definition and selection of the temporal aspects is determined by the markup language, as well as the properties or specified attributes of every one of them. For this reason, in order to carry through the process of temporal annotation to completion,

it is necessary to identify and normalise these expressions, i.e. to carry out a semantic interpretation. At the present time a guide is available in English, Chinese and Italian, but there is also an ongoing adaptation to Spanish.[543] Since we are dealing with a Spanish historical corpus, it has been necessary to adapt the guide in accordance to the linguistic variety. It is relevant to note that for the time being no studies have been undertaken about the correspondence in old Castilian in TimeML. So far the ground on which work about temporal extraction has been done in newspaper or legal texts.[544]

After identification of temporal expressions in Renaissance Castilian, the next step has been the use of TimeML annotation. For this purpose the Document Type Definition (DTD) contains all the elements, values and attributes TimeML is made up of. From the beginning XML has been chosen as markup metalanguage.

Next an example is shown of the corpus of normalization of these temporal expressions in TimeML where the guide values appear: TIMEX3, EVENT, SIGNAL and TLINK.

"La de v.m. de 15 deste he recebido en este dia" (that from your honour of the 15 th of this month I have received on this day)

```
<SIGNAL sid="sid1">
de
</SIGNAL>
<TIMEX3 tid="tid12" type="DATE" value="1567-05-15"
```

543   Roser Saurí et al., "Annotating Time Expressions in Spanish, TimeML Annotation Guidelines" (in Press).
544   Frank Schilder and Andrew McCulloh, "Temporal information extraction from legal documents", In *Annotating, Extracting and Reasoning about Time and Events*, eds. Katz, G., Pustejovsky, J., Schilder, F., Dagstuhl Seminar Proceedings, vol. 05151 (2005), http://drops.dagstuhl.de/opus/volltexte/2005/313 (accessed February 26, 2010).

```
anchorTimeID="tid11">
15 deste
</TIMEX3>
<EVENT eid="eid28" aspect="PERFECTIVE" mood="NONE"
pos="VERB" vform="NONE"
class="OCCURRENCE" tense="PRESENT" stem="RECIBIR">
recebido
</EVENT>
<SIGNAL sid="sid2">
en
</SIGNAL>
<TIMEX3  tid="tid13"  type="DATE"  value="1567-05-28"
anchorTimeID="tid11">
este dia
</TIMEX3>
<TIMEX3 tid="tid11" type="DATE" value="1567-05-28" >
28 de mayo de 1567
</TIMEX3>

<TLINK  relType="INCLUDEs"  lid="lid31"  timeID="tid13"
relatedToEventInstance="eid28"
signalId=" sid2"/>
<TLINK relType="BEFORE" lid="lid31" timeID="tid12"rela
tedToEventInstance="eid28"
signalId=" sid1"/>
```

The TLINKs represent the temporal relationships existing between two events, two times, or between an event and a time. In

the example, the event would be "he recebido" (I have received), which is accompanied by two temporal expressions, *"15 deste" (the 15th of this month) and "este dia"* (*this day)*. The temporal relationships between these three elements are marked with the TLINK tag.

It is relevant to remember that the XML is not inherent to the TimeML since the latter may turn into other formats; as a matter of fact, a web annotation tool is being developed that generates data in database tables from text annotation[545].

Towards creating tools for automatically extracting temporal information from text

Approach by patterns has been used for detection of temporal expressions. The first step consists of manual identification of temporal expressions, which implies the necessary preprocessing of the corpus; subsequently patterns are generated in order to generalise the rules. Once this is achieved, we intend to incorporate those patterns automatically, stage which is still to be developed, although we will describe the rules deduced.

There are various tools for the detection and normalisation of temporal information in English, French, Spanish and Chinese[546],

545   BAT: Brandeis Annotation Tool: http://www.timeml.org/site/bat/ (accessed February 26, 2010).

546   Inderjeet Mani and George Wilson, "Robust Temporal Processing of News", (paper presented at *38th Annual Meeting of the Association for Computational Linguistics,* proceedings, New Brunswick, New Jersey, 2000); Nikolai Vazov, "A System for Extraction of Temporal Expressions from French Texts based on Syntactic and Semantic Constraints", (paper presented at *ACL Workshop on Temporal and Spatial Information Processing*, proceedings, 96–103, 2001); Estela Saquete et al., "Recognizing and Tagging Temporal Expressions in Spanish", (paper presented at workshop on *Annotation Standards for Temporal Information in Natural Language*, LREC 2002); Wu Mingli et al., "CTEMP: A Chinese Temporal Parser for Extracting and Normalizing Temporal Information", (paper presented *Second International Joint Conference on Natural Language Processing*, proceedings (IJCNLP'05), Jeju Island, Korea, October 11- 13, 694–706,

however none of them may be employed for our study case. Taking into account the chosen corpus, a set of grammatical rules have been deduced regardless of the context, which have been related to the tags and values of the TimeML. In that respect, it should be mentioned that the difference between the temporal expression and the extents defined by the markup language (i.e. when each temporal expression begins and ends) has been respected. By agreement the TIMEX3's extents do not include the initial preposition which is marked with the SIGNAL tag.

The next table shows the grammatical rules of the temporal expressions present in Simón Ruiz's letters for the subsequent development of an automatic identifier of all the timexes. The classification in table 2 provides the range of granularities of the TimeML; so far we have not taken into account the nature of these expressions to make the classification, whether defined, deictic, undetermined or fuzzy; this would be needed for the creation of a normaliser of expressions, since it is necessary, among other things, to keep the context in mind. On the other hand, the units appearing in the corpus may be seen on the table, so it is anticipated that the number of rules could grow when considering a larger corpus. The time units (TU) appearing on the corpus are day, week,

2005).

DATES	
Ndia+ de+ Nmes+ (de)+Naño (DM)+ díaN+ del /de+ ComplTemp/Nmes AdvTemp DM/QUANT+ TU Nmes art+ TU/Nsem+ adj hace/hacia/ha/a+ QUANT+ TU: TU+ha/a	primero de dizienbre 1568 (December 1 st, 1568) 15 del pasado (15 of last month) Oy (today) este día /algún dia (this day) ottubre (October) los días pasados (the last days) ha tantos días (many days ago) días a (days ago)

DAY TIMES	
art+ TU/num	la mañana (this morning)

DURATION	
DM/art + TU QUANT/num+ TU	este mes (this month) muchos años (many years ago)

SET	
FREQ+ num/art+ TU	cada ocho días (every 8 days)

Ndía (1 | 2 | 3 | 4 | 5 |…31) Ndia (primero | secundo |…) Nsem (lunes | martes |…domingo) Nmes (henero | Otubre | dezienbre | noviembre |…) Naño (1568 | 1569 | 1570 | 1571 |…) TU (dia | mes | año | semana | berano |…) ComplTemp (prezente | pasado | dicho | deste |…) AdvTemp: (oy | ayer | mañana |…) DM (este | ese|…) QUANT (mucho | poco | tanto | algun |…) art (el | la | los |…) FREQ (cada | todos |…) num (1 | 2 | 3 | 4 | 5 |…100)

Table 2. Grammatical rules for recognition of temporal expressions.

Incorporation of TimeML as part of a geodatabase

After having annotated the corpus in TimeML we go on with the integration of the text in the geographic information system. The GIS have different data formats, all of which assume a database-oriented structuring of information: geodatabases, tables in MS Access, tables in MS Excel (with certain restrictions), etc. The porting of TimeML annotation into any of these formats is guaranteed by the fact that TimeML does not allow for redundant entities, and hence it provides a stable, predictable structure, so that a relational database could be designed to store the information contained by TimeML annotation. The following structure (figure 1) contains all the elements, attributes and values of TimeML. However, this design can be modified if we do not want to consider all entities of the markup language or want to include others.
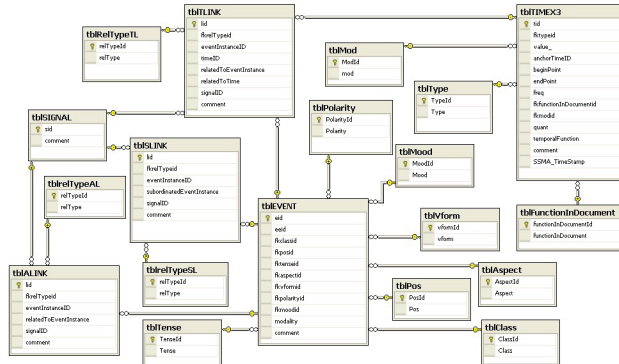

Fig.1. Structure of TimeML based on the DTD in the geodatabase; every tag contains its corresponding table.

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Before having the information within the geodatabase, it is necessary to consider further processing of the attributes of language, especially with respect to the entity timex3, in order to be able to operate with them in geodatabase. Finally, the visualization of the annotated corpus will depend on characteristics the historical events described; for example if we were dealing with the binnacle of a ship's captain, the representation of shipping routes, goods transported, oceanic currents, winds and storms could be emphasized, but if the corpus was made up of texts describing land voyages, the representation details would be substantially different, highlighting other aspects. In this regard, as far as representation of the linguistic annotation of the corpus is concerned, we may add that this is a future line of research which involves the dynamic display of events.

Results and discussion

This work represents an initial step addresses to extend semantic temporal incorporating TimeML into a GIS. For the time being the GIS have imposed a simple structure concerning time that does not suit the needs and uses of the historical GIS. In certain recent scientific investigations it is pointed out that text documents provide a lexical and semantic richness which is not usually found in these geographic tools, and they are oriented toward natural language narratives[547]. For this reason the use of TimeML in historical GIS applications is advocated to incorporate a more complex semantic structure and the use of natural language from

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547   Katheleen Stewart Hornsby and Naicong Li, "Conceptual framework for modeling dynamic paths from natural language expressions", Transactions in GIS 13(s1), 27–45 (2009).

historical texts. As mentioned, the application of the semantics field to the GIS has been addressed from different fronts, the spatial information orientation has been prevalent by and large, while the temporal semantics has been neglected, and the research work focused on the use of corpora has been scarce. The advantages that can point out of using TimeML are its standard character, its format as a database, its applicability to any language since it has got a defined grammar, and above all its properties, since it enables ordering of events in a timeline. TimeML, like other markup languages, allows massive treatment of text information.

Some of the limitations to carry out the proposal have been described:

(a) to achieve the representation of the temporal information tagged in the corpus, the Geographic Information System should have a spatio-temporal database allowing storage and querying of the information coming from the corpus, i.e. a temporal GIS reflecting the TimeML;

(b) corpora tagged in TimeML are scarce for languages other than English which prevents the use of automatic learning techniques and gives rise to the use of semi-automatic and manual annotation;

(c) adaptation of TimeML to old Castilian is needed to facilitate identification of temporal expressions in this type of texts. In the future we intend to achieve the recognition and normalisation of temporal expressions in wider Spanish historical corpora, as well as the integration of temporal and spatial linguistic annotation. Furthermore, we will continue deepen in the processing of temporal expressions in order to achieve a more efficient analysis and representation in a GIS.

The operational structure of historical maritime shipping: a general review of knowledge discovery tools

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Introduction

Contemporary maritime-economic history is dominated by two opposite approaches. The first type of studies looks for macroeconomic trade developments on the basis of numeric data. In this approach, names of shipmasters and ships are not processed and data about the movement of ships is reduced to a number attached to specific places.[548] Typically, this approach is used in positivist analyses of historical phenomena.[549] The second approach

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548   For examples, see: Jake Th. Knoppers, *Dutch Trade with Russia from the time of Peter I to Alexander I: a quantitative study in eighteenth century shipping (*Montréal: ICES, 1976), 3 vols. Pierrick Pourchasse, *Le commerce du Nord. La France et le commerce de l'Europe septentrionale au XVIIIe siècle* (Rennes : Presses Universitaires de Rennes, 2006) 390 pp. J. Thomas Lindblad, *Sweden's Trade with the Dutch Republic, 1738-1795: a quantitative analysis of the relationship between economic growth and international trade in the eighteenth century (*Assen: Van Gorcum, 1982*) xiii, 201 pp.* George Welling, *The Prize of Neutrality: trade relations between Amsterdam and North America 1771-1817: a study in computational history* (PhD diss., University of Groningen, 1998) ix, 261 pp. Simon Van Brakel, "Statistische en andere gegevens betreffende onzen handel en scheepvaart op Rusland gedurende de 18e eeuw, " *Bijdragen en mededeelingen van het historisch genootschap* 34 (1913): 350-405. Milja Van Tielhof, *The 'Mother of all trades': the Baltic grain trade in Amsterdam from the late 16th to the early 19th century* (Leiden: Brill, 2002) xvii, 370, [15] pp.
549   Kurt Dopfer, Werner Scheltjens, "Why is economic history an evolutionary science? Unified rule approach employing Dutch maritime shipping as exemplar" (unpublished research article).

does include alphanumeric data about the name of the shipmaster, the ship and its movement. Often this type of maritime-economic studies takes the form of small-scale sample studies in which data about one or two years is examined in detail and represented in the form of a narrative account.[550] In some cases, sample studies constitute part of larger quantitative studies of the first type; then, they are used to prove the reliability of a source on the basis of in extenso comparison with one or more similar sources.[551]

The goal of this paper is to present a set of general analytical tools that are deemed to help researchers of maritime history to discover significant elements of the structure of historical maritime shipping that would otherwise remain invisible. It is hoped that these tools will help researchers of maritime history to generate new hypotheses. The tools in this paper are based on existing methods for exploratory data analysis. Their theoretic foundation is evolutionary; the tools are constructed in such a way that they allow to discern and interpret processes of origination, adoption and retention.[552]

550   For examples, see: Pieter Dekker, "Friese schippers op de Amsterdamse Oostzeevaart in 1731," *It beaken: meidielingen fan de Fryske Akademy* 39 (1977): 229-262. George Welling, "Price-supply relations on the Amsterdam staple-market 1778," in *From Dunkirk to Danzig: Shipping and Trade in the North Sea and the Baltic*, 1350-1850, ed. W.G. Heeres et.al. (Hilversum: s.n., 1988). Piet Boon, "West Friesland and the Sound (1681-1720). Sound Toll Registers, Sound Toll Tables and the Facts in West Friesland," in: ibidem, 171-189.

551   Jake Th. Knoppers, "A Comparison of the Sound Toll Accounts and the Amsterdam Galjootsgeldregisters," *Scandinavian Economic History Review* 24 (1976): 93-113.

552   Kurt Dopfer and Jason Potts, *The general Theory of Economic Evolution* (London/New York: Routledge, 2008) 134 pp.

Case

The presented set of tools was applied previously in a historical case-study analysis.[553] The historical case is as follows. In 1703, the Russian Czar Peter the Great founded St. Petersburg with the particular intention of creating a "New Amsterdam". All of Russia's policies (foreign and domestic) were directed towards the realization of this goal.[554] The execution of Peter the Great's plan succeeded in the course of one generation. Already in 1724, St. Petersburg had actually become Russia's "New Amsterdam". The basic questions of the casestudy are the following: (1) Did the foundation of the city of St.Petersburg in the first half of the eighteenth century change the structure of Dutch maritime shipping? (2) What particular influence did the foundation of this Russian city have on the Dutch shipping services industry? These questions have been studied at length, using historical ship movement data as a source and applying a variety of analytical techniques.

The specific geographical and temporal boundaries of the case-study play a secondary role in this methodological paper. The presented set of tools is of a general nature and is hoped to be of interest to maritime historians regardless of their specific geographical and temporal areas of specialization.

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553 Werner Scheltjens, D*e invloed van ruimtelijke verandering op operationele strategieën in de vroeg-moderne Nederlandse scheepvaart: een case-study over de Nederlandse scheepvaart in de Finse Golf en op Archangel*, 1703-1740 (Groningen: Barkhuis Publishing, 2009) 320 pp.

554 Jurij Michajlovič Lotman, *Semiotika goroda i gorodskoj kultury: Peterburg* (Tartu: Tartuskij Gosudarstvennyj Universitet, 1984) 139 pp. M. Burovskij, *Peterburg kak geografičeskij fenomen* (Sankt-Peterburg: Aletejja, 2003) 30-74. Maks Ėngman, *Finljandcy v Peterburge* (Sankt-Peterburg: Evropejskij Dom, 2005) 70-75. Kenneth Rolf Hellebust, "The Real St. Petersburg," *The Russian Review*, 62 (2003): 495-507.

Case-study results

The results of the case study differ fundamentally from the findings of previous analyses conducted on the basis of a positivist (neoclassical) approach. Based on quantification, one the one hand, of all arrivals at Amsterdam of Dutch ships coming from Russian ports in the Baltic and White Seas, and, on the other hand, of the tonnage carried by each ship as well as the size of each ship, the Canadian historian Jake Th. Knoppers has reached the following conclusions[555]: (1) Given the tonnage of cargo exported, St. Petersburg never replaced Archangel; (2) Given the number of arrivals at Amsterdam, Narva and Archangel would be more important for Dutch shipping with Russia than St. Petersburg throughout the entire eighteenth century; (3) Given the size of the ships, the importance of St. Petersburg for Dutch shipping with Russia should be valued even lower than what the previous parameters already suggested.

Thanks to the different analytical techniques, in which the restrictive properties of quantification were avoided in favor of bottom-up aggregation preserving individual economic actions, it could be shown that the population of Dutch shipmasters active on the St. Petersburg route represented a new population with characteristics quite different from those of the Archangel or Narva populations. The size of the ships used on the St.Petersburg route was indeed smaller, but the value of the goods carried (not their tonnage!) was much larger. The effect of the foundation of St. Petersburg on Dutch shipping with Russia could consequently be

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555   Knoppers, *Dutch trade with Russia,* vol. 1.

described as a continuous structural change that originated in individual carriers, evolved into populations of shipmasters and eventually lead to re-coordination in (part of) the Dutch maritime shipping services industry.

Datasets

Ship movement data were taken from three different sources: the Danish Sound Toll Registers, the Dutch Galjootsgeldregisters, and the Schipgeldregister of Abraham Kramer.[556] All three datasets based on these sources cover roughly the time period 1703-1740, i.e. the period of this case-study. Their spatial coverage is complementary. The Danish Sound Toll Registers provide information about passages of Dutch ships through the Sound at Elsinore and allow reconstructing maritime traffic between the Baltic and North Seas. The Galjootsgeldregisters record arrivals of Dutch ships from the Baltic and White Seas at Amsterdam. The Schipgeldregister of Abraham Kramer lists Dutch ships departing at Amsterdam on a trip to Archangel.

Throughout the paper, reference will be made to structural elements of the Navigocorpus database on European maritime shipping in the 17th and 18th centuries[557] of which all three datasets are now part. The constituent parts of the Navigocorpus database structure are points (geographical locations), cargoes, taxes and

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556   Stadsarchief Amsterdam, nr. 6. Archief van de Directie van de Moscovische Handel (DMH), inv. nrs. 58-61, 123. Stadsarchief Amsterdam, nr. 78. Archief van de Directie van de Oostersche Handel en Reederijen, inv. nrs. 96-99.Tresoar, Leeuwarden: Microfilm copy of the Danish Sound toll registers. Films 167-209.

557   ANR 342/2007 Navigocorpus. Silvia Marzagalli, "Présentation du projet Navigocorpus,". Revue d'Histoire Maritime 8 (2007): 337-339.

actions. For movement data analysis, Navigocorpus' uniform point definition fields play a key role. These fields define each point (or geographical location) registered in the database by its name, function, rang and observation status in a ship movement registration.

Figure 4: Navigocorpus database structure, uniform point definition fields

Structure of the paper

In the remainder of this paper, I will focus on the techniques that have been applied in the case-study analysis. Specifically, I will describe and assess computational aggregation and information visualization of entities and populations of shipmasters and the variety of forms these technical procedures took.[558] Guided by

558   Database operations, like deconstruction of the data into data items, standardization and reconstruction, will not be discussed separately, although they are fundamental for the successful execution of the consequent technical procedures of computational aggregation and information visualization. A large body of literature on database operations in historical studies exists. For relevant information with regard to (maritime-)historical databases, see: Welling, *The Prize of Neutrality*, 80-112. Gerrit Bloothooft, "Assessment of Systems for Nominal Retrieval and Historical record Linkage," *Computers and the Humanities* 32 (1998): 39-56. J. van Bavel, *Demografische reproductie en sociale evolutie: Geboortebeperking in Leuven 1846-1910* (PhD Diss., University of Leuven, 2001) 363-408. Peter Wakelin, "Comprehensive Computerisation of a very large documentary Source: the Portbooks Project at Wolverhampton Polytechnic," *History and*

Peuquet and Andrienko's typology of basic descriptive tasks[559], I will try to provide a general overview of the techniques previously applied in the case-study analysis. Only general tasks aimed at the discovery of entity and population behaviour will be discussed, and within this selection of tasks only those that question time in a general way (i.e. tools for the analysis of time moments are left out).

Application of these limitations results in a selection of four basic descriptive tasks that are deemed appropriate to discover the operational structure of historical maritime shipping. The four basic descriptive tasks question entities, populations, locations and sets of locations. The list could be extended with time-related questions, but this falls out of the scope of this paper.[560]

Describe the characteristics of:			
	What?	Where?	When?
1	A given entity	At a point of gravity	During the time period from t1 to t2
2	A given entity	At a set of points	During the time period from t1 to t2
3	A set of entities	At a point of gravity	During the time period from t1 to t2
4	A set of entities	At a set of points	During the time period from t1 to t2

Table 1: Overview of basic knowledge discovery tasks. Based on Andrienko, Andrienko and Gatalsky (2003)

Each of these tasks will be developed further making a distinction between three cognitive operations - identification, classification and comparison - , which define the structure and lay-out of the analytical tools corresponding to the basic descriptive tasks. It must be clear from the outset that the paper will focus solely on providing a general review of analytical tools and not on their interpretation. All the tools that will be presented below are 'simple' tools that do not require programming skills. Two main tools were developed with the aim of facilitating the above mentioned cognitive operations for the four basic descriptive tasks introduced earlier.

Each of them has a range of possible visualizations and I will focus explicitly on those visualizations that are - in my opinion - the most advantageous for the identification of entities and locations. Some of these visualizations will be abstract; some others will make use of GIS tools. In the following paragraphs, I will briefly address the structure of a basic data series upon which exploratory data analysis can be based (§ 5). Then, I will present the two main tools that were developed with the aim of facilitating identification and classification for the selected basic descriptive tasks (§ 6 and § 7). In paragraph § 8, I return to the case-study for a brief application of the presented tools in a comparative setting. The paper closes with an overview of tasks, cognitive operations and their respective tools followed by an overall assessment of the presented method (§ 9 and § 10).

Basic Data series

All the analytical tools presented in this paper are built upon data series that contains at least the following variables: name of the shipmaster, time, homeport, direction of the movement and one or more points of gravity with their respective functions in a registered geographical trajectory.[561] In these data series, the number of registrations is counted for previously established time intervals (usually one year) and for a previously established time period. The result is a dataset that captures the movement in time of individual shipmasters. This dataset is in fact a two-dimensional abstraction of the registered movement of individual shipmasters and serves as the basis for further exploration of historical ship movement data by means of identification, classification and comparison.

Variables						Time interval	Time interval	Time interval
name	date	homeport	A (dep)	O (obs)	T (dest)	Count	Count	Count
Registration of movement						Registration of frequency		

Name of the shipmaster = Entity

Table 2: Basic data series schema. A = departure, O = observation, T = destination

Several quantifications are immediately possible using the basic data series table, but only one of them will be discussed briefly

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561   It is important to note that the name of a shipmaster and/or the name of a ship are used to identify *economic entities* in historical ship movement data rather than specific persons or ships.

here, because of the specific interest they present for the topic of
this paper. It is the frequency distribution of ports of departure in
the Baltic for Dutch shipmasters at time moments 1715 and 1740. In
this example, Dutch shipmasters constitute the given set of entities.
It should be noted that a set of entities can be defined on the basis
of a number of criteria ranging from identical homeport to sharing
destination, cargo carried or even certain temporal characteristics.
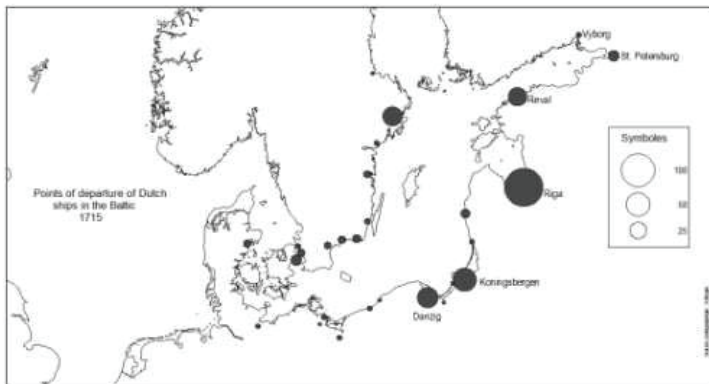
Figure 5: Points of departure of Dutch ships in the Baltic 1715. Map created
by J.P. Dedieu (ENS de Lyon)

Comparison of the frequency distribution of ports of
departure in the Baltic for Dutch shipmasters in 1715 and 1740
immediately brings to light a series of changes. First of all, it can be
seen that the Swedish coast was abandoned in 1740, while in 1715
several Swedish ports were used by Dutch shipmasters. Secondly, a
clear upswing in the amount of ship movements can be read from

the maps, providing evidence for the disturbing effects of warfare in the Baltic on maritime shipping. Thirdly, and most importantly, comparison of the 1715 and 1740 maps shows that intensive shipping to the Gulf of Finland must have emerged after 1715. On the 1740 map, the Gulf of Finland, with its ports St. Petersburg, Narva, Vyborg, Reval, and Helsingfors, appears as one of the core regions of Dutch shipping activity in the Baltic, next to the main ports Riga, Koningsbergen and Danzig.
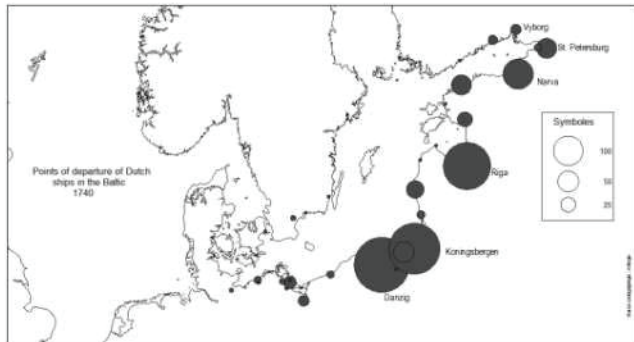

Figure 6: Points of departure of Dutch ships in the Baltic 1740. Map created by J.P. Dedieu (ENS de Lyon)

Entity Dynamic tools

The first analytical tool is drawn up for individual ports (regardless of their actual function in a ship movement, including homeport, port of departure, port of destination and intermediary ports of call). It contains information about the behaviour of

individual shipmasters, groups of shipmasters and their relation to one specified point of gravity. The first tool is called entity dynamics tools and it answers to the demands of the first and third descriptive tasks.

Identification

Identification of entities in the entity dynamics tool can take a variety of forms, but is most efficient when one point of gravity and one direction of movement are isolated. In Navigocorpus, this is done by selecting one point of gravity, one direction and adding either destination of departure information to the selection.[562] The variable is the name of the shipmaster, the selected point of destination/departure is the constant, and the number of corresponding registrations is calculated for a previously defined time interval. In its most basic form, the result of this identification process is visualized as a two-dimensional table. Another type of identification singles out one route (by selecting one point of departure, one point of observation and one final destination) and is constructed in analogy with the first type. Again, in its most basic form, the results are visualized as a two-dimensional table.

In our case, Dutch shipmasters constitute the set of entities. The points of gravity that have been studied are Archangel, Narva, Vyborg and St. Petersburg. The time period that has been analyzed is 1703-1740, with further distinction made between the periods 1703-1717, 1718-1724, 1725-1731 and 1732-1740. The time interval was set at one year throughout the casestudy. In the following table,

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562   In Navigocorpus, the choice between destination and departure is made by selecting the corresponding function in the uniform point definition fields. A stands for point of departure, O for point of observation and T for final destination.

the entities (i.e. the shipmasters) registered as departing from point of gravity Narva in the period 1725-1731 are identified.

naam	voornaam	TOTAL	PATTERN	PERIOD	1725	1726	1727	1728	1729	1730	1731	CR
EIKES	ABRAHAM	14	7	7	2	2	2	2	2	2	2	0,50
ANNES	HIELKE	13	7	7	2	1	2	2	2	2	2	0,54
HANSES	TJEERD	13	7	7	2	2	2	1	2	2	2	0,54
HANSES	THOMAS	12	6	6		2	2	2	2	2	2	0,50
OUDEWAGEN	PIETER (wa, ams)	12	7	7	1	2	2	1	2	2	2	0,58
ROZENBOOM	HIDDE	11	6	6	2	2	2	2	1	2		0,55
SIEMENS	JAN	11	6	6		2	2	2	2	1	2	0,55
SIEMENS	PIETER (hi)	11	7	7	2	1	2	2	2	2	1	0,64
ANNES	IEPE	10	7	7	1	1	2	2	1	1	2	0,70
BOM [??]	ANDRIES	10	7	7	1	1	1	2	1	2	2	0,70
BROERS	LOURENS	10	7	7	1	1	2	2	2	1	1	0,70
BROERS	SIEBOUT	10	6	6		2	2	1	1	2	2	0,60
DAM	TJEERD	10	6	6		3	1	2	1	2	1	0,60
GOFFES	JAKOB	10	7	7	1	2	1	1	2	2	1	0,70
JENTJES	BROER	10	6	6	1	2	2	1	2	2		0,60
WIJNBERG	EVERT	10	6	6		1	2	2	1	2	2	0,60
AGES	SIBBELE	9	3+3	7	2	2	2		1	1	1	0,78
BENEDICTUS	TJEERD	9	5+1	7	1	2	2	2	1		1	0,78
GERRITS	JAN	9	5+1	7	1		2	1	1	2	2	0,78
HEFT	ABE Broers	9	5	5			1	2	2	2	2	0,56
HESSELS	SIBBELE	9	4+1	7	2			2	1	2	2	0,78
SJOERDS	HERE	9	6	6		1	1	2	2	2	1	0,67
TEEKES	SIBBELE	9	5+2	7	2	2	1	2		1	1	0,78

Figure 7: Entity dynamics tool, basic table. Fragment representing Dutch shipping from Narva 1725-1731

Classification

Next to the basic visualization as a table, the results of identification of shipmasters in the entity dynamics tool can be aggregated in several ways. Most importantly, classification addresses (a) the dynamics of populations, (b) the operational strategies of individual entities and (c) the behaviour of set of entities (or populations). The latter are done applying two related classification techniques, namely: operational pattern classification and the pattern density rate. The former is the result

of the classification of entities according to their status within a
population.

a. Entity status classification

Entity status classification is based on four parameters:
new and known entity supply, incidental participation (once)
and regular participation (more than once) of entities. During
classification all four parameters are related to the total supply
(i.e. the size of a population during a certain time interval), both in
absolute numbers and as relative shares.

CLASS	DEFINITION
new	shipmasters that appear for the first time at a given location or set of locations during the examined time period
known	shipmasters that have been registered before at a given location or set of locations during the examined time period
once	shipmasters that appear only once at a given location or set of locations during the examined time period
rest	all shipmasters that appear more than once at a given location or set of locations during the examined time period

Figure 8 : Entity status classification: definitions

The underlying assumption for entity status classification is
that a route continuously needs new supply in order to develop and
avoid stagnation. However, a route cannot survive without stability
(i.e. a share of total supply that is ascertained for a number of
consecutive years). Through comparison of the share of new supply
and the share of "known participants" on a certain route at a certain
point in time, various stages in the development of populations can
be addressed and analyzed. It allows determining when stagnation
becomes a problem, in other words: it allows determining when

a route is starting to decline. The first two visualizations of entity status classification are charts containing information about the total annual number of shipmasters active in one port and the amount of new shipmasters entering the port in one year, as opposed to the number of shipmasters that had already been in this port previously. The first chart contains absolute numbers; the second one shows relative positions.
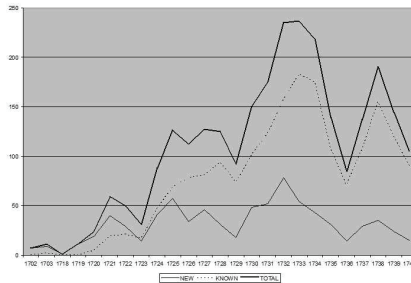

Figure 9: Entity classification status, Dutch shipmasters on Narva route 1702-1740, absolute numbers
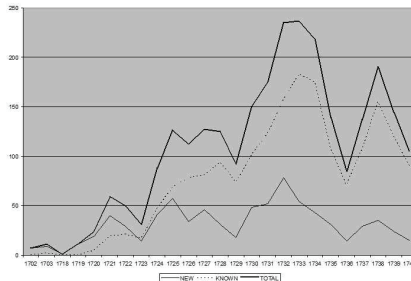

Figure 10: Entity status classification, Dutch shipmasters on Narva route 1702-1740, relative positions

The third chart visualizes the relation between shipmasters that have been to the port under study only once as opposed to the relative number of shipmasters that made more than one journey to this port.
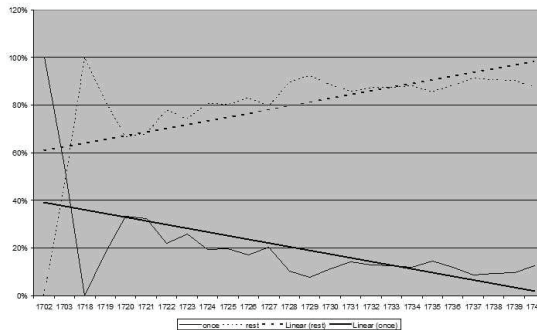

Figure 11: Entity status classification, Dutch shipmasters on Narva route, incidental vs. regular members

Entity status classification is a vertical type of aggregation, in which behaviour of individual shipmasters is quantified for given time intervals (in the charts above the time period was 1725-1731, the time interval one year).

b. Operational pattern classification

The second type of classification based on the entity dynamics tool is operational pattern classification, providing breakdowns of the individual behavioural patterns that shipmasters adopted in their activities on one route. Operational pattern

classification is a horizontal type of classification based on the entity dynamics table. It provides summary views of operational patterns of individual shipmasters active at a certain location during a given time period. A summary view of the individual patterns captured by operational pattern classification has total time elapsed and total number of (return) voyages as its parameters. This summary view can be enlarged with a pattern density rate (PDR), which is discussed in the following paragraph.

# of voyages	# of shipmasters	pattern	# of shipmasters per pattern	AVG time frame	PDR
1	61	1	61	1	1
2	18	2	8	2	1
		1+1	10	3,9	1,95
3	1	2+1	1	5	1,67
4	6	4	1	4	1
		2+1+1	1	6	1,5
		2+2	1	5	1,25
		3+1	3	5,33	1,33
5	4	5	1	5	1
		2+2+1	1	7	1,4
		4+1	2	6	1,2
6	1	5+1	1	7	1,17
7	1	7	1	7	1

Figure 12: Operational pattern classification for Dutch shipmasters on Archangel route

c. Pattern density rate

The third type of classification based on the entity dynamics table is the pattern density rate (PDR), which is a calculation of the time frame of a particular operational pattern divided by the number of voyages executed within this time frame. The closer the pattern density rate comes to the benchmark (BM) (i.e. the empirically established highest possible number of return voyages

to a port of call within a period of time), the smaller the time frame in which the shipmaster carried out his voyages. The pattern density rate can be read as the number of years one shipmaster needs to carry out one journey to a certain destination, or to a certain set of destinations.

The information contained in the pattern density rate is a relevant addition to the frequency distribution introduced earlier (see § 5). Using the benchmark as a tool for classification, distinction can be made between four main operational strategy types. The first type is that of one-time-only participants. The second type is that of sporadic (incidental) participants who exported/imported from time to time from a certain location or a pre-defined group of locations. The third type is that of regular participants, who were active or even very active in shipping to or from a certain location or a pre-defined group of locations during a restricted period of time.

The fourth type is that of specialized participants, who have an operational pattern that shows (quasi) permanent presence in shipping to or from a certain location or a pre-defined group of locations.

participation frequency	Pattern density rate	type of participant	type of pattern
more than once	BM < PDR < BM*2	specialized participant	continuous participation
	BM*2 ≤ PDR ≤ BM*3	regular participant	temporary appearance
	PDR > BM*3	sporadic participant	dispers pattern
once	n/a	one-time only	n/a

Figure 13: Operational pattern classification: a typology

In this paper, the pattern density rate is based on the maximal number of Sound passages from the Baltic to the Atlantic. If no such

passage registrations are available, benchmarking must be done for specific destinations (or destination clusters) or for specific homeports (or homeport clusters). If this is the case, the frequency distribution introduced earlier will be of help discovering relevant destinations or homeports for a given location or set of locations.

Spatial dynamics tool

The second analytical tool is the spatial dynamics tool. This tool is based on the entity dynamics tool. It provides details about the "membership" of shipmasters in various populations and consists of comparative charts based on the entity dynamics tool. The spatial dynamics tool allows (1) discerning when shipmasters changed routes, while also (2) providing the necessary information to establish whether or not such changes occurred in the patterns of many shipmasters at the same time. Moreover, the spatial change tool allows (3) establishing the long term effects of spatial shifts, making it possible to separate permanent from temporary shifts, while also (4) making evolutions towards the establishment of operational patterns with greater complexity visible.

Identification

The characteristics of a given entity at a set of locations during time period t1 to t2 form the basic information units of the spatial dynamics tool, which has a primary focus on sets of entities (populations). This said, the discovery task that is elementary with regard to the entity must not necessarily be described separately. The spatial characteristics of entities and sets of entities can be

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identified through one shared procedure.

The identification process starts with a given set of locations and a given time period. Entities matching these criteria are selected from the basic data series. Then, the selected data is deduplicated and matched, using existing record linkage techniques[563]. The resulting data set is a time series in which each appearance of an entity at one or more of the given locations is highlighted. One possible lay-out of the spatial dynamics tool is the following:

NUMBER	NAME	FIRST NAME	1718	1719	1720	1721	1722	1723	1724
1	ABRAHAMS	JAN				V	V	N	N
2	AGES	PIETER		A					
3	AGES	REINER							N
4	AGES	SIERD			V	V			
5	AGES	THOMAS		N	N		N	N	N
6	AKKER	JAN			V				
7	ALBERTS	HESSEL				N	N		
8	ALBERTS	WILLEM					N	N	N
9	ALEFS	THOMAS			S				
10	ALLERTS	PIER						A	
11	ALLES	DOUWE				N	V		
12	ANDRIES	SIBBELE					N		N/V
13	ANNES	DOEDE					N		N
14	ANNES	FEIKE							S
15	ANNES	SIEMEN		V	V	N			
16	ANSKES	AGE		N	A	N			
17	ARENDS	HENDRIK			V				
18	ATSES	SIEBE						V	
19	AUKES	ANDRIES				N			
20	AUKES	FOLKERT							N
21	AUKES	REINER		N		N			
22	AUKES	SIBBELE		V	V	V			

Figure 14: Spatial dynamics tool. Fragment representing the spatial dynamics of Dutch shipping in the Gulf of Finland and on Archangel, 1718-1724. Abbreviations: A = Archangel, N = Narva, S = St. Petersburg, V = Vyborg.

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563   In the presented case-study, record linkage was done in a semi-automated way. Names, first names and patronymics were matched with a thesaurus of Dutch names first. The non-matches were attributed standard names on the basis of a previously defined decision-making process. Automatic record linkage procedures are widely available nowadays. See for instance Link Plus for open-source name deduplication and matching software that uses Soundex and NYSIIS algorithms.

Obviously, the above visualization has its limitations: there is no frequency data available in this representation. This loss is limlited when the calling frequency of the set of entities is low, but it becomes a problem when it is higher and more different locations can be called at within the given time interval. Other visualization techniques will have to be sought for to tackle this problem.

While the spatial dynamics of a single entity can be read directly from the above representation, it is in some cases more adequate to reconstruct the individual shipmaster's activities in detail. This elaboration can be seen as an extension to the spatial dynamics tool, in the sense that the changes that occurred in the shipmasters' activities are now described without losing frequency data and with the possibility of including other data types (cargo data, ship data, etc). Reconstruction of the operational pattern of a single shipmaster involves a process that starts with data selection in one or more basic data series. The next steps are comparison, matching and compilation into one metafile, which can be visualized using GIS tools or represented in a descriptive way.

HOP, KLAAS GERRITS (Gerritse(n), G., P.), from Warder, Hindeloopen
Ships: Stam (1712), Jonge Stam (Jonge Star, 1715-1721, SL: 170 / 164 / 154), Christina (1725,
SL: 165)
1. 20-4-1712. Amsterdam (O) to Archangel (T). Charterer: Lups, Jacob for 7100 f. [sr714]
2. 1-6-1715. Amsterdam (O) to Archangel (T). Charterer: Thesingh for 6600 f. [sr902]
3. Amsterdam – Archangel – Amsterdam
    1. 25-7-1716. Amsterdam (O) to Archangel (T). Bij 't last. [sr1016]
    2. 4-4-1718. Archangel (A) to Amsterdam (O). CL: 170 [ggr11800]
4. Amsterdam – Archangel – Amsterdam
    1. 15-7-1718. Amsterdam (O) to Archangel (T). Charterer: Hoesem,
      van for 5800 f. [sr1090]
    2. 24-3-1719. Archangel (A) to Amsterdam (O). CL: 210 [ggr11845]
5. Amsterdam – Archangel – Amsterdam
    1. 1719. Amsterdam (O) to Archangel (T). Charterer: Hoesem, van
      for 5700 f. [sr1121]
    2. 22-11-1719. Archangel (A) to Amsterdam (O). CL: 190 [ggr11865]
6. Amsterdam – Archangel – Amsterdam
    1. 15-5-1720. Amsterdam (O) to Archangel (T). Bij 't last. Spent
      winter in Archangel; returned to Amsterdam in 1721 [sr1193]
    2. 19-11-1721. Archangel (A) to Amsterdam (O). CL: 170 [ggr11932]
7. Unknown – Narva – Amsterdam
    1. 21-12-1724. Narva (A) to Amsterdam (T) via Elsinore (O). 30 ½:18
      rks [dsr1560]
    2. 14-4-1725. Narva (A) to Amsterdam (O). CL: 175 [ggr2756]
8. Amsterdam – Narva – Amsterdam
    1. 7-5-1725. Amsterdam (A) to Narva (T) via Elsinore (O). Ballast
      [dsr1581]
    2. 6-7-1725. Narva (A) to Amsterdam (T) via Elsinore (O). 47 rks
      [dsr1662]
    3. 17-8-1725. Narva (A) to Amsterdam (O). CL: 171 [ggr12465]
9. Amsterdam – Narva – Amsterdam
    1. 5-9-1725. Amsterdam (A) to Narva (T) via Elsinore (O). Ballast
      [dsr1620]
    2. 30-11-1725. Narva (A) to Amsterdam (T) via Elsinore (O). 30 ½
      rks [dsr1725]
    3. 25-1-1726. Narva (A) to Amsterdam (O). CL: 165 [ggr12581]

Figure 15: Individual career pattern, including Navigocorpus' uniform
point definition fields

    Minor differences between data items in the various
sources must be described in order to make the underlying match

scoring process traceable. Reconstruction of the operations of one single shipmaster is a time-consuming process and will therefore seldom be used at length in maritime-historical research. However, it may serve well as a starting point for further analysis, and when geospatial visualization of the shipmaster's operations is applied, it may also be used as a tool for hypothesis generation.

Classification

Classification of the data identified in the spatial dynamics tool is done either from an entity point of view or from a locational point of view. In the former case, entities are classified according to the frequency of route changes occurring in the operational patterns of shipmasters at a given set of locations. In the latter case, entities are classified according to the spatial characteristics of route changes occurring in the operational patterns of shipmasters at a given location. The outcome of these classifications varies depending on the angle chosen. Abstract views of route changes are deemed most appropriate in both cases. Below is a summary view of the number of shipmasters that carried out their last return voyage to Archangel in a given year. The chart below visualizes the abandonment of the Archangel route, as a consequence of Peter the Great's restrictive economic policies towards this White Sea port. The turnaround on the Archangel route took place between 1718 and 1723. At least 10 shipmasters executed their last voyage to Archangel each year, with a peak of 19 in 1723.
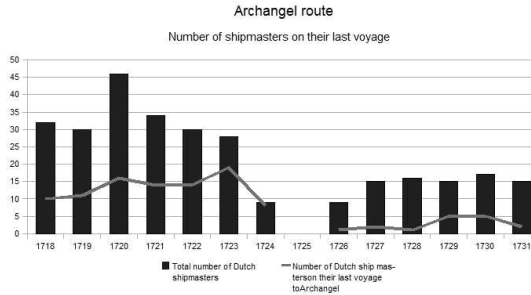
Figure 16: The abandonment of the Archangel route by Dutch shipmasters,
1718-1731

The above representation addresses the spatial
characteristics of a particular kind of route change (i.e. abandonment
of a route). It does not allow establishing where the shipmaster went
after having abandoned the Archangel route. When classification
is done according to the frequency of route changes occurring in
the operational patterns of shipmasters at a given set of locations,
the spatial characteristics of these route changes can be addressed.
When concentrating further on the shipmasters who executed their
last return voyage to Archangel in the period 1718-1724, a structural
spatial evolution can be identified. 33 Dutch shipmasters shifted
from participation on the Archangel route to participation on one
of the routes to the eastern part of the Gulf of Finland. For seven
of them, this shift was a one-off event; the other 26 would remain
active in the eastern part of the Gulf of Finland in second half of the

1720s and sometimes up to the early 1730s. That almost 1/3 of the Dutch shipmasters formerly active on the Archangel route would venture an attempt on the routes to the eastern part of the Gulf of Finland is striking; that this did not remain a one-off event for the majority of them is even more unexpected.

Classification of spatial dynamics does not necessarily involve route changes. The Narva route developed at great pace and was dominated by a group of regular participants involved in the exportation of timber from Narva to the Netherlands. Specialization as a basic characteristic of the Narva population finds expression in the following graph, which visualizes the dynamics of the share of 'new' and 'known' population members. Clearly, the dominant behaviour was that of risk limitation and efficiency gains through the adoption of an operational strategy based on regularity and repetition. Finally, in the Narva population a new rule emerged after 1724, namely that of executing two return voyages from Amsterdam to Narva in the course of one year.
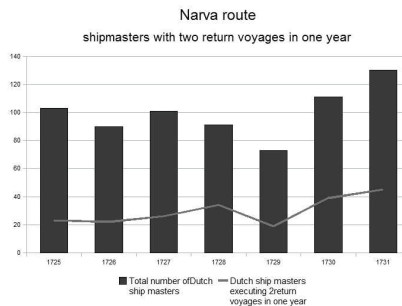

Figure 17: Dutch shipmasters on Narva route, two return voyages in one year, 1725-1731 COMPARISON

Comparison

Comparison is a key feature of both the entity and spatial dynamics tools and it encompasses all the abstractions, aggregations and visualizations described in the previous paragraphs. Comparison may be as simple as comparing previous abstract and geospatial representations of identified and classified ship movement data, but it may also involve complex procedures when large time periods and large sets of locations are compared. After having introduced some key aspects of the abandonment of the Archangel route and the emergence of the Narva route, we will conclude our review of analytical tools by comparing the previous graphs and tables with the results acquired for the population of Dutch shipmasters active at St.Petersburg.
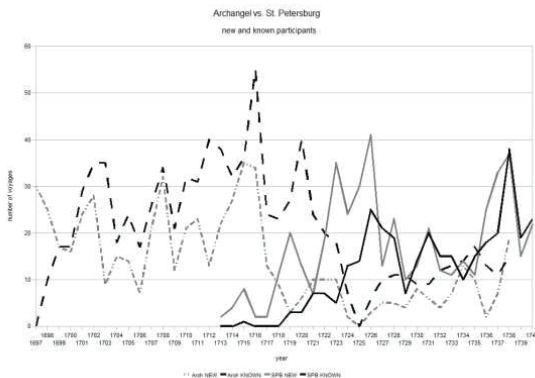

Figure 18: Archangel vs. St. Petersburg, new and known participants, 1697-1740

The continuous lines represent the emergence of the St. Petersburg population in absolute numbers, distinguishing between 'new' and 'known' population members; the dotted lines plot the evolution of new and known participants on the Archangel route. We can acknowledge the fact that the decline of the Archangel population and the emergence of the St. Petersburg population coincided, and it is fair to say that this is related to the foundation of St. Petersburg and its subsequent promotion of (foreign) trade through this new gateway (see § 1 and § 2). It would, however, be wrong to assume that Dutch shipping moved from the Archangel route to the St. Petersburg route for one fundamental reason: both routes had distinct populations, each with their own properties, and – as can be seen on the visualization below – no significant overlap existed between them.
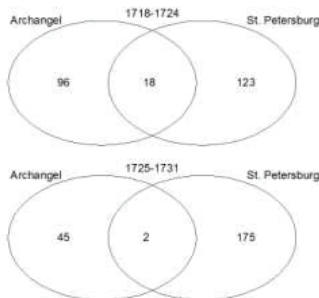

Figure 19: Visualization of overlap between populations of Dutch shipmasters active on Archangel and St. Petersburg routes, 1718-1731

In the above visualization, the interchangeability of routes is represented by the respective quantities of population members

appearing on both routes during a pre-defined time period. In the time period 1718-1724 these respective percentages were 18,75 % and 14,63 %, in the time period 1725-1731 they diminished to 4,44 % and 1,14% for the Archangel and St. Petersburg route respectively.

The distinctive properties of the St. Petersburg route in Dutch maritime shipping also appear very clearly when pattern density rate and operational pattern classification are compared for the Archangel, Narva and St. Petersburg routes.
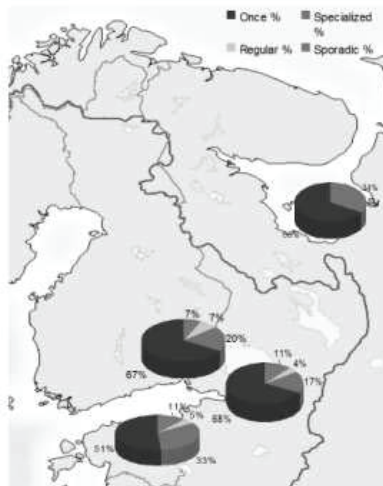

Figure 20: Operational pattern classification for Archangel, Narva, St. Petersburg and Vyborg populations of Dutch shipmasters, 1732-1740

The shares of 'new' and 'known' participants on the St. Petersburg route differ greatly from the population dynamics on the Narva route. Partly, this is due to the distinct location characteristics

of Narva and St. Petersburg, which influenced the size of the ships that could be used for shipping to these destinations.[564] More fundamental, however, are the distinct operational strategies that were applied by either population. This difference is directly related to the position of Narva and St. Petersburg in the Baltic commercial system. Narva was a timber export outlet exclusively, while St. Petersburg was Russia's new gateway for both imports and exports of valuable goods and finished products. The St. Petersburg population seems to have been a population that constituted of many 'incidental' participants, meaning that these participants appeared on the St. Petersburg route when there were specific opportunities to seize. The Narva population, on the other hand, was dominated by specific groups of shipmasters with the same origin, which participated regularly on the same route. Finally, comparison of the spatial dynamics of Dutch shipping to Archangel, Narva, Vyborg and St. Petersburg brings to light the clustering of the Archangel, Narva and Vyborg routes as complementary destinations, while the St. Petersburg route continues to stand out. This is established on the basis of a comparison of the populations of each of the four destinations studied. The number of population members shared with another population is used as a measure for overlap between destinations.

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564   The harbour of St. Petersburg was shallow and hard to reach for the large ships that called at Narva, Vyborg and Archangel. For more information, see: Robert E. Jones, "Getting the Goods to St. Petersburg: Water transport from the interior 1703-1811," *Slavic Review* 43 (1984): 413-433.
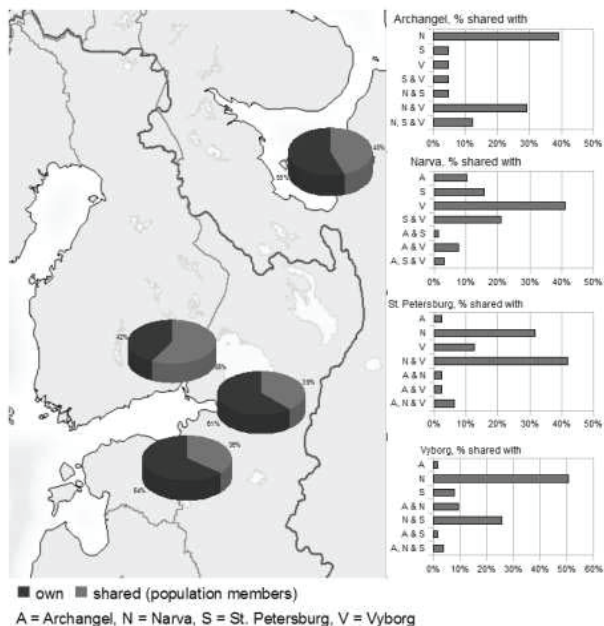
Figure 21: Overlap between Archangel, Narva, St. Petersburg and Vyborg populations of Dutch shipmasters as indicator of clustering of destinations, 1732-1740

Summary

In the previous paragraphs, two main analytical tools were introduced: the entity dynamics tool (§ 6) and the spatial dynamics tool (§ 7). For both tools, identification and classification possibilities were examined and represented, providing a total of eight visualizations with a basic data series (§ 5) as common

starting point. The identification step of the entity dynamics tool resulted in the entity dynamics table (§ 6.1). This table then served as the basis for three classification operations covering entity status (§ 6.2.1), operational patterns (§ 6.2.2) and pattern density (§ 6.2.3). The identification step of the spatial dynamics tool resulted in the spatial dynamics table (§ 7.1), which in turn was the starting point for establishing the entity and spatial characteristics of route changes (§ 7.2). Comparison – the third cognitive operation in our survey (§ 8) – took four different forms: (1) comparison of representations resulting from identification and classification (figure 15), (2) visualization of the interchangeability of routes (figure 16), (3) comparison of pattern density rates for sets of entities (figure 17) and (4) clustering of routes (figure 18).

Describe the characteristics of:				
	What?	Where?	When?	Tool?
1	A given entity	At a point of gravity	During the time period from t1 to t2	Entity dynamics tool
2	A given entity	At a set of points	During the time period from t1 to t2	Spatial dynamics tool
3	A set of entities	At a point of gravity	During the time period from t1 to t2	Entity dynamics tool
4	A set of entities	At a set of points	During the time period from t1 to t2	Spatial dynamics tool

Table 3: Overview of basic knowledge discovery tasks with indication of corresponding tools

Assessment

The entity and spatial dynamics tools address the entrepreneurial dimension of maritime transportation. The entity dynamics tool allows analyzing entrepreneurial behaviour, both for individuals and for groups (populations). It provides simple tools for the identification, classification and comparison of some key features of entrepreneurial behaviour. The spatial dynamics tool has a primary focus on space, and its interaction with entrepreneurial behaviour. The spatial dynamics tool provides detailed and multi-faceted insights in the spatial properties of entrepreneurial behaviour, both for individuals and for groups. Temporary and permanent changes in the operational strategies of populations of shipmasters become apparent in the abstract and geographical spatial visualization of maritime shipping operations. Time is omnipresent in all of the presented tools, which is a necessary prerequisite for their successful application in evolutionary analysis.

The combination of both information science and evolutionary economics carries a great promise. Maritime-historical research could become an acknowledged scientific discipline with a clear research agenda. One potential area of research is the study of operational knowledge clusters and their role in the development of maritime shipping in the early-modern period. The underlying idea is that the combination of information science and the general analytical framework of evolutionary economics provide the necessary techniques and analytical tools to "show how competition between (...) agents, based on the core evolutionary

principles of variety, selection and retention, may produce distinct economic regions sharing properties that differentiate them from elsewhere".[565] Moreover, the evolutionary information science that maritime shipping should become, could serve as a profound basis for analyzing "how the emergent properties of economic agents and places co-evolve and lead to different trajectories of economic development over space".[566]

This article only presents what could become a typology of analytical tools that can be created employing the principles of exploratory data analysis. Further work is necessary to include a clearly defined cargo dimension in the scope of the analysis. Data series covering longer time periods need to be made available so that the presented tools can be elaborated in that direction as well. On the one hand, the general nature of data analysis using the entity dynamics and spatial change tools already makes comparison of distant time periods viable. A range of novel topics for future maritime-historical research can easily be generated with the simple tools at hand. On the other hand, long time series will - if explored using the tools presented in this paper – enhance the opportunities to analyse trends, fluctuations and structural changes in the operational structure of maritime shipping in a comprehensive way, preserving at all times the central role of the individual in all economic activity, even when data is aggregated, classified and compared.

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565   Jürgen Essletzbichler and David L. Rigby, "Exploring evolutionary economic geographies," *Journal of Economic Geography* 7 (2007): 549-571.
566   Ibidem.

Authors bibliography

Ana Crespo Solana: PhD in Geography and History (Universidad de Cádiz, Spain) and Master in Latinoamerican History (Universidad Internacional de Andalucía). She has worked as a research fellow, invited lecturer and associate professor at several universities and research centres in Spain, Belgium, Germany and The Netherlands; and granted by several institutions. In 2003 she received the Ramon y Cajal Award of the Spanish Ministry of Science and Innovation. Currently she is Tenured Scientist and Professor specialized in Caribbean and Atlantic History at the Spanish National Research Council (CSIC). She has lead several research project on Atlantic Economic and Social History and Spatial Humanities as: DynCoopNet (Dynamic Complexity of Cooperation-Based Self-Organizing Commercial Networks in the First Global Age), TECT/EUROCORES/ ESF, with J.B Owens; NACOM (Nations and Communities: comparative perspectives in Atlantic History) and GlobalNEt, both funded by the Spanish Ministry of Science and Innovation. She is a member of several Editorial, Advisory Board and scientific committee; and reviewer of the Standing Committee for the Humanities of the European Science Foundation, the Spanish Agency for International Cooperation (AECYD), etc. She is

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David Alonso García. Ph. D. for the Complutense University of Madrid, Department of Modern History where he teaches since 2004. His area of expertise includes fiscal history and financial networks during XVIth, both in Spain and Europe. He is principal investigator in DynCoopNet network (managed by Drs. J. W. Owens and A. Crespo), supported by European Science Foundation, where the key topic attends to the role of cooperation within merchant networks. Currently he leads a research project for using GIS technologies in order to analyze Castilian tax system between 15th- 16th centuries. He organized, with Dra. Ana Crespo, a session in XVth World Economic History Congress (Utrecht, 2009), about "Selforganizing networks and Trading Cooperation: GIS tools in the visualization of the Atlantic Economic expansion (1400-1800)". He has been visiting fellow in the London School of Economics (2000), Università di Roma "La Sapienza" (2001), University of California, Los Angeles (UCLA, 2006) and Università di Roma Tre (2010). He has published a numerous studies, articles and books included in international databases

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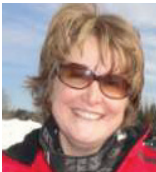
Professor Monica Wachowicz is currently working at the University of New Brunswick, Canada. Her research is focussed on discovering mobility patterns evolving from social interactions and developing the next generation of services that can translate mobility patterns into actionable information about societal lifestyle expectations and needs. Her research interests are in the areas of geographic knowledge discovery,

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