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FROM GEOGRAPHIC INFORMATION SYSTEMS (GISy) TO GEOGRAPHIC INFORMATION SCIENCE (GISc)

Introduction

The term Geographic Information System (GISy) refers to a set of hard and soft technologies used for managing a map. Geographic Information Science (GISc) describes the underlying science that provides the basis for GISys. The question that has emerged in recent years is how exactly GISytems (which are principally concerned with technological problems) and GISc (which is tasked with using the traditional instruments of scientific research to support the work of multiple, collaborating disciplines) actually fit into the context of scientific work and research. The two terms are not interchangeable; treating them as synonyms precludes the possibility of acknowledging their unique qualities and characteristics. GISy, therefore, shall be understood in the sense of technological instruments, manufactured products; GISc is concerned with research instruments; the reference is purely scientific. GISy have developed in step with the evolution of hard and soft technologies. In their early days, they also effectively drew on advances in applied science, and were themselves the subject of research, but beyond a sufficient level of development further evolution was achieved largely through advances in the technologies used. In this sense, they are similar to digital writing instruments: new "inventions" and innovative approaches are rare, yet the ways in which they are applied continues to evolve. Unlike the alphanumeric interpretation of letters and numbers proposed by a word-processing file, however, the data handled by GISy instruments relates to georeferenced items, points and vectors. The instruments of GISc, meanwhile, have emerged more recently. They owe their existence – and subsequent development – to trends in the evolution of scientific research and, in particular, the need for a multidisciplinary approach involving the potential interaction of a great number of quantitative and qualitative data of the most heterogeneous nature. GISy were first used in Italy at the Italian National Research Council (CNR) in the 1980s (Montanari, 2010). The early

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years of that decade saw the arrival of the first off-the-shelf ARC/INFO software from the USA. The relative cost of these systems was two hundred times what it is today, and the hardware needed to run them – also sourced from the States – had a footprint ten thousand times as large as that of a contemporary laptop. Operators, thirty years ago, would have had to enter a prefabricated cabin in the courtyard of the CNUCE/CNR building where the majestic IBM 3090 – which could harness as much as 128MB – operated in temperature-controlled conditions, with GISy data transported on rolls of magnetic tape with a density of 1,600 bytes per inch. In the last thirty years, the majority of progress has been in the qualities of the equipment used (Montanari, 1989). Today, it is possible to run ArcGIS Advanced on a portable PC weighing little more than a kilogram and transfer data on a 32,000,000,000-byte flash drive less than an inch long. The intervening years have effectively not witnessed new "inventions", just a moderate level of what we might term "innovation" and a lot of improvements to the technology. The result has been a gradual decrease in research levels, especially in the social sciences and geography. A coloured map of a territory may once have qualified as a scientific product, in and of itself, but no longer. It can only become one through its contents, the meanings embodied within it, its capacity to interpret reality and guide policy management (Montanari, King, 1994; Montanari, Magnarapa, 1998). What follows here is an overarching summary of the literature that anticipated, and at times followed, the passage from GISy to GISc from the 1980s to the first two decades of the 21st century. The most important points of reference are found in the work of geographers Waldo Tobler and Michael F. Goodchild. Tobler is celebrated as the formulator, in the 1970s, of the "first law of geography" (TFL), which would also find popularity among scholars in many other disciplines. Goodchild's research, meanwhile, focused on the field of Geographic Information. Having witnessed, first hand, the development of the hard and soft technologies used in the creation of GISy, he went on to demonstrate the operational limitations of the software involved. In one paper, Goodchild pointed out that, by then, even a primary-school child could use a GISy and produce coloured maps of great beauty that were nonetheless largely devoid of meaning. Writing in the 1990s, he emphasised the need for a return to science in Geographic Information, as in other fields. Tobler was a student at the University of Washington in Seattle. He counted numerous great names from the world of geography among his teachers, and others – who would contribute to the development of the field – among his peers. TFL enjoyed peaks and troughs of popularity over the years, but its fortunes were revitalised when it was acknowledged as a linchpin of Geographic Information, and thus as a key instrument in GISy and subsequently in GISc. The new, central role played by TFL in scientific research was mirrored in the personal fortunes of

Tobler and Goodchild, who both joined the faculty at the University of California, Santa Barbara, Tobler in 1977 and Goodchild in 1988.

GISy and GISc are not abstract concepts. Anyone who conducts research work in the field of geography – and the social sciences in general – must at some point grapple with the complexity of certain situations, especially during phases of research that demand a multidisciplinary approach. To address the complexity of this sort of research, the scholar must turn to the instruments developed in the field of geography; among these, those pertaining to the TFL, GISy and GISc are indispensable. At the International Geographical Union (IGU) Conference held in Quebec City in Canada from 5-11 August 2018, Goodchild was invited to give a "Luminary Talk" on "Geography and GISc". Over about an hour, he revisited the principal transitions between GISy and GISc in relation to what he understood as "geography". I was pleased to be able to take advantage of the opportunity to hear him speak, and thus to better organise the considerations that form the basis of this contribution. Sadly, Waldo Tobler died on 20 February 2018, and was thus unable to attend the Quebec City conference.

Geographic Information

As early as the second half of the 1950s, meteorologists and biologists in Sweden and the UK were experimenting with forms of automated cartography. Longley et al. (2005) identifies 1963 as the year in which the field of Geographic Information passed from invention to innovation, with the Canada Geographic Information System developed in partnership with the Canada Land Inventory (Montanari, 2010). According to Hornby et al. (1963), the adjective "geographic" can be used to qualify all those elements that pertain to physical or economic geography. The term "information" indicates an instrument that has been created to disseminate knowledge about geographic phenomena. As in many cases, the English is rooted in Latin: the Latin verb "informare" incorporates the meanings of depicting by displaying, drawing, exhibiting, describing, representing. Pietro Coppo implies a useful definition of "Geographia" in his 1528 work De Summa Totius Orbis, in which he includes – in addition to inhabited settlements – isolated churches, mills and inns, much like a modern geographic information system might do. Once the initial sense of "novelty" had died down, the potential of GISy was the subject of a number of critical evaluations – especially in the United States – which sought to define such systems within the standard limits of a software package. For Burrough (1986), a GISy is an instrument for collecting, organising, retrieving and processing spatial data from the real world, albeit he also acknowledges their capacity to achieve more specific aims. Mogorovich (2010) highlights the contrast between traditional printed maps and their electronic counterparts: when the former is augmented with information beyond a reasonable limit, it risks becoming illegible. The same cannot be said of a geographic database, which enables the management of an effectively limitless number of entities of different types. Aronoff (1989) characterises GISy in terms of four fundamental sets of capabilities for handling georeferenced data: (i) entry, (ii) data management (storage and retrieval), (iii) manipulation and analysis, and (iv) output. For some, a GISy is an instrument that can help in decision-making and the management of any attribute that has to be analysed from a geographic standpoint: it combines the functionalities of its constituent hardware, software and data to collect, manage, analyse and display all forms of information that relate to geography. Mogorovich (2010) is quick to underline the role of GISy and their significance, maintaining that a GISy is more than a mere drafting tool: rather than a paradigm of cartography – where the ultimate aim is at most a partially accurate symbolic representation – it corresponds far more closely to a paradigm of geography itself, namely the description and analysis of physical and anthropic phenomenon.

Issues with Geographic Information

Definitions for the English abbreviation are as numerous as they are heterogeneous. For some, a GISy is a software system for managing geographic data; for others, it is a way of organising and giving structure to a body of data and the society they represent. The analogy proposed by Burrough (1986) – a toolbox, in which each tool is configured to solve a specific problem – underlines the potential of the GISy instrument, effectively extolling its technical qualities. Other definitions are more strictly concerned with function, insomuch as they identify a sequence of function categories from the source of information to map production, and thus final usage. Clarke (1997) talks of automated systems for collecting, storing, retrieving, analysing and displaying spatial data. Longley et al. (2005) links the definition to different usage types. While, for most users, a GIS is no more than a digital cartography repository, (i) for administrators and planners it is a computerised instrument for solving geographic problems, (ii) for researchers it is a system that helps with decision-making, (iii) in service and infrastructure management it is an automated inventory of the geographic distribution of facilities and equipment, (iv) for scientists it serves to render visible those elements of geographic information that would otherwise remain invisible, and (v) in planning and natural-resource management it is an instrument for carrying out operations involving geographic data that would be too tedious, costly and inaccurate if effected manually. GIS technology was initially thought – particularly in the UK and United States – to mark a great step forward, a radical shift that would empower the geographer and geographic research. Ronald Abler has made a number of significant contributions on this question, both in relation to his role as president of, first, the AAG (1985-1986) and, second, the IGU (2008-2012), and his academic work in the field of geography of media and communication. Abler (1988) asserts that, for geography, GISy potentially represented a technological revolution analogous to what the microscope, telescope and computer had meant for medicine, biology and the other natural sciences, one that could dissolve the dichotomy between the regional-systematic and human-physical approaches that had blighted the field for so long. GISy were heralded as the instrument of a new geographic culture that could help resolve the discipline's internal conflicts. Many of the solutions proposed in relation to the problems of managing GISy, and geographic data in general, can be traced to the experiences of the cultural revolution of the 1960s, one effect of which was to help the diffusion of a more quantitative approach among geographers. Previously, a culture had emerged among American geographers that was rooted in psychological research, and used a largely nomothetic or idiographic approach with (i) an experiment-based methodology, (ii) a clinical methodology, or (iii) a psychometric methodology using tests. More specifically, the nomothetic approach involves studying phenomena in terms of generalised features, while the idiographic approach is concerned with specific elements and individual experience. Both involve observation but whereas, in a nomothetic set-up, the researcher starts from a hypothesis, a sort of prediction, in the idiographic approach the explanation is arrived at at the end of the research process. Rather than a hypothetical form of understanding, a "pre-diction", the latter approach therefore yields an interpretive understanding, a "retro-diction", so to speak. One of the most stimulating debates to light up the field of geography is the exchange between Schaefer (1953) and Hartshorne (1954) on the question of approach and methodology in geographic research. Indeed, even though Schaefer passed away in the year his article was published, his work has steered generations of geographers towards a nomothetic understanding of a number of issues, such as geomorphology and the theory of the "central place". Bunge (1962) takes an even more decisive stand, asserting that science is an exclusively nomothetic matter, and that geography is a science and, as such, defined by its field of knowledge, i.e. the Earth as the home of humanity. Every science has a field of empirical application, and a theoretical field. Much work has been carried out on geographic facts, but none in regard to its theory. In any work of a scientific nature, the principles that form the basis of research relate to values that can be applied at any point in space and time; indeed, it is inconceivable that a general principle can be found to be applicable in only one specific place and time. What we have, in this case, is a nomothetic approach rooted in positivistic philosophy in which scientific knowledge is understood as the result of a long and validated process of experimentation. The specific properties of a specific place as considered within a limited period of time, meanwhile, are the domain of idiographic knowledge, a descriptive, anecdotal and journalistic form of as yet unverified understanding whose veracity cannot be checked. With the contemporary large-scale use of digital communication, this sort of idiographic knowledge has been able to spread more easily, often on a basis of erroneous, if not intentionally false, information.

The values and principles of geographic research: the debate in the USA

Geographic information should be held to exacting standards in terms of: (i) clarity, (ii) simplicity, (iii) universality, and (iv) accuracy. Bunge (1962) made a telling contribution to many of the following decades' advances in quantitative geography and the science of geographic information, albeit without really anticipating in any form what is today held to be an emphasis on computerisation and networks. To properly appreciate the different elements of the debate, it is important to remember that at the end of the 1950s Bunge graduated as a young man from the University of Washington, where the likes of Garrison, Ullman and Hudson were part of the faculty. Among his fellow students were Berry and Tobler. This younger generation would, in turn, influence an important group of geographers in America, but also a number in Britain, including King (1969), Curry, Yeates, Haggett (1966) and – in particular –Chorley (Chorley, Haggett, 1967), who had a key role in the spread of GISy in the UK. The spread of the nomothetic approach continued for at least a decade, before dropping off as interest in quantitative methodologies declined. There was a revival of interest, however, as GISy began to emerge in the 1990s, together with a renewed interest in the work and approaches developed in previous decades. Taylor (1990) described GISy as the heir to both the quantitative revolution of the 1950s and '60s and positivist spatial science, and for these reasons went as far as to define it as no less than the "positivists' revenge". Meanwhile, in considering GISy's potential contribution to the field, Abler (1993) noted the minimalist role assumed by the geographers themselves, accusing them of frequently disguising a caricature of geography in pretty theorisations and handsome maps. Here, the term "caricature" is used intentionally to underline the exaggeration effected through the deliberate use of archetypes, but frequently also the grotesque distortion of concepts, components and characteristics.

Geographic Information: echoes beyond the USA

While the debate continued in the United States, the 1980s saw the emergence of concrete initiatives in other countries where the adoption of GISy by organs of public and private administration was deemed an effective strategy in the pursuit of better living standards (Montanari, 1990; Campari et al., 1991; Mogorovich, Montanari, 1993). In the United Kingdom, the Economic and Social Research Council (ESRC), whose purview extends to the field of geography, has encouraged the application of GISy in health service provision and contingency planning. Indeed, in 1988, issue 63 of the ESRC Newsletter was dedicated entirely to the use of GISy. Around the same time, the European Commission's Environment Directorate General launched the CORINE programme for the years 1985-1989. This experimental programme would see the creation of a GISy that would enable the EEC to operate more effectively across its various areas of responsibility in terms of calibrating, planning, preparing and ultimately delivering directives and programmes for regional development. In 1985, the British government set up a Committee of Enquiry, which was to report back within a term of two years advising on the handling of geographic information in the United Kingdom, taking account of modern developments in information technology and market needs. Over its two-year duration, the "Committee on Handling of Geographic Information" was chaired by Lord Chorley (it became known as the "Chorley Committee"). In 1987, it delivered a report that addressed the following areas in turn: (i) digital topographic mapping; (ii) availability of data; (iii) linking of data sets; (iv) awareness; (v) education and training; (vi) research and development; and (vii) the role of government, and machinery for coordination. The Chorley Report encouraged the use of GISy in the UK, identified the costs involved and the investments required to support the necessary research and training. Between 1987 and 1990, in addition to his work in promoting GISy in the UK, Lord Chorley was president of the Royal Geographical Society. The Report also recommended the creation of a Centre for Geographic Information, which – in order to be most effective – would not be under the control of a single department but have links with the whole government. It would provide the government with advice on the implementation of new technologies, and the government would be responsible for its funding. The government, at that time headed by Margaret Thatcher, decided that any such centre would need to (i) provide a forum for both manufacturers and users, (ii) promote awareness of

GI's potential benefits for the community, and (iii) provide impartial information and advice to users. However, they also concluded that it would need to be self-sufficient and, crucially, self-financing. Lord Chorley (1988) offered his own interpretation of the report that bore his name, while a number of respected academics made further contributions, raising the issue of disseminating the report's conclusions among the wider public. These included Rhind and Mounsey (1988) and Tomlinson (1987), who published the report itself as an appendix to his article. The Association for Geographic Information was established in 1989 with Lord Chorley as its first president, a position he held for almost twenty years before stepping down in 2007.

Tobler's First Law of Geography (TFL) and the usefulness of geographic information

As an instrument, a GISy can be likened to a generic tool such as a hammer or spanner insofar as it can be used for multiple purposes, with different functions for representing a wide variety of geographic information. Numerous studies have attempted to sound the depths of geographic information and approach the limits to which our understanding can be generalised by examining those principles and laws that can be identified through experimental investigation. Scholars who have taken a critical stance on GISy have thus sought to better harness the systems' potential for drawing general principles from specific data. In this area, the contribution of Waldo Tobler (1970) in relation to the results of a study of his on Detroit (1970) – for which an animated visualisation of the results has recently come to light, perhaps the first of its kind to be produced in the university setting: https://visionscarto.net/hyperelliptical-projections – is of particular interest. Between 1956 and 2018, Tobler published 47 peer-reviewed journal papers, receiving 3,200 citations according to Web of Science, and 7,330 citations and 18,000 "reads" according to Research Gate. Despite these figures, he is mostly remembered for what has been termed Tobler's First Law of Geography (TFL): "All things are related, but nearby things are more related than distant things". In actual fact, this is not so much a law as an observation. Goodchild (2003) maintains that the term "law" is especially problematic. Many would say that human populations do not display behaviour that can be equated to a "law", and that the sole truth lies in the distinction between who "does" and who "does not", between "yes" and "no". All the same, TFL is a foundational concept in the analysis of geographic data insofar as it considers the relation between the data to be implicit. It is the reason geography can be considered an essential element of any multidisciplinary approach. If the presuppositions on which the Law rests were not widely validated, geographic examination of models would not have any meaning. TFL can be dated to 1970, when Tobler was forty. For the rest of his life, until the day he died, he continued to publish and carry out research to support this fundamental principle. His contributions extended into the computerisation of cartography, of which he was a pioneer, the mathematical study of geographic space, and the fields of cellular, fractal and computational geography. His studies were designed, using models and simulations, to assess hypotheses, carry out observations or even predict phenomena. The evolution of GISy in the last decades of the 20th century brought renewed interest in TFL. The Law makes it possible, for instance, to treat large areas as homogenous, and represent them in the form of a polygon rather than through a large number of points. The world is infinitely complex, but GISy databases are able to use the implications of TFL to find a compromise between excessively heavy and excessively sparse levels of sampling. With new interest comes new debate. The Annals of the AAG sponsored a forum on the question of TFL, which resulted in a publication with an introduction by Sui (2004). In the interests of debate, Tobler (2004) was given the right of reply. He asserted that there is a fundamental property of geography – one that was easy enough to explain – by virtue of which things that are nearer to one another are more related than those that are distant from one another.

Geographic Information Science (GISc) and Self-organizing Maps (SOM)

According to Goodchild (2009), there is a lack of a consistent framework for organising the functionality of GISy. In some cases, GISy technology has anticipated developments in theory, with the consequence that terminology has been introduced independently of the existence of rigorous and sufficiently defined sources. The technologies of spatial science, which are following a path of accelerated advancement and expansion laid down by rapid developments in ICT, are turning to the instruments of GISc in search of solutions to a great number of fundamental problems. These demands can only be satisfied through collaboration between numerous disciplines including statistics, mathematics, physics, computing, geography, cognitive psychology and political science. GISc is the scientific study of the general principles that govern the acquisition, handling, processing, analysis, storage and visualisation of geographic information; a GISy is a software package designed to perform these functions. According to Goodchild (2009), GISc took its first steps towards the end of the 1980s as GISy became widespread and the need emerged to better understand the basic principles that would underpin our understanding of this environment. One solution was to apply the principles of the self-organising map (SOM) to GISy. A SOM is a particular architecture for artificial neural networks that has been used to great benefit in representing two-dimensional maps in a way that solves problems with data clustering (Ramazzotti, 2013; Londei, 2013). A new phase in the use of SOMs and their potential adoption in the field of GISc was initiated by Agarwal and Skupin (2008). In Europe, since the implementation of Framework Programme 7, communicating the results of what can be highly complex computational processes with end-users, stakeholders and public bodies has been a required objective for research projects funded by the European Union. This has made the use of GISc in interpreting results from SOMs a particularly valuable strategy (Montanari, 2013). Goodchild (2008) – who was the first to introduce the concept of GISc nearly three decades ago (Goodchild, 1992) – explains that an SOM describes objects that are not necessarily localised in geographic space, and that indeed, by their very nature, bear no reference to their localisation. In contrast, GISc starts with the assumption that all objects of interest are georeferenced. For this reason, disciplines that have worked with SOMs and those that have used GISy and GISc have previously shared very few areas of common interest and, subsequently, have rarely collaborated with one another. Bação et al. (2008) have recognised the need to transform large georeferenced databases into useful "knowledge" instruments and, in this spirit, numerous researchers have sought to work towards the creation of a mass-produced product. However, with this goal still to be realised, there is an ongoing need for research exploring ways of adapting the SOM approach to the needs and functionalities of GISc. In many fields, the way objects are classified is based on similarities in their attributes. In GISc, the concept of similarity regards both the parameters of "attribute space" and "geographic space", whereby it takes on the value of proximity (Montanari, 2014). Bação et al. (2008) propose that TFL be incorporated within the SOM model in a way that generates a parallel between geographic proximity and the proximity of attribute values. In general terms, TFL distinguishes geography from other disciplines insofar as it assigns a specific and significant role to the spatial component. TFL cannot be considered an exhaustive concept in and of itself but it can form the basis for extrapolating systems (using sophisticated techniques) that offer more effective forms of geo-spatial interpretation, improve our understanding of the present and even anticipate what might happen in the future. Longley et al. (2005) maintain that it is virtually inconceivable that two maps of different phenomena over the same area would not reveal some similarities. As such, they assert that «the assumption of zero spatial autocorrelation that is made by many methods of statistical inference is in direct contradiction to Tobler's Law» (Longley et al., 2005, p. 104). The Complex Adaptive Systems (CAS) model suggests that proximity is sufficient as a parameter, given that interactions at a local level, albeit simple, can contribute to the formation of global situations that are often much more complex and cannot be fully predicted or monitored. Montello et al. (2003) introduced the idea of the visualisation of the semantic content of non-spatial information. The principle of "spatialisation" is based on distance-similarity. According to TFL, distance is what determines similarity. The "First Law of Cognitive Geography" (FLCG), however, takes an analogous set of starting propositions but arrives at the opposite conclusion, that in spatialisation it is similarity that determines distance. The FLCG is founded on empirical studies in which participants were asked to rate the similarity between documents depicted as points in spatialised displays. Further support for the use of SOMs in GISc comes from Tobler and Wineberg (1971) which describes how cuneiform tablets could be used to identify the location of ancient urban settlements in Cappadocia. Their analysis was based on the number of tablets found in one settlement that made reference to other settlements. The authors express their conviction that mathematical models based on contemporary urban structures have a temporally and geographically invariant structure and can be applied to the Cappadocia situation. The study did not make any reference to existing routes or itineraries; rather it was only concerned with the distance between settlements, on which sole basis it was possible to determine the relative positions of other towns and thus arrive at a prediction of their geographic coordinates. Tobler (2004) looks back at a number of observations and critiques of the author's work. In the Cappadocia example, the spatial gravity model was turned on its head to identify the location of vanished settlements. He also notes that spatial autocorrelation is not always positive, as is clear from the NIMBY phenomenon in contemporary society. For Goodchild (2008), meanwhile, the SOM is a more than just another addition to the spatial analytic toolbox; for him, it constitutes a new paradigm for Exploratory Spatial Data Analysis (ESDA) and spatial data mining. What is more, the increasing use of SOMs and the positive results they can offer raise some significant questions for GISc in general, and the GISc research agenda in particular.

Multidiscplinarity and science dissemination: the role of geographic information

Since the early years of the new millennium, the world's scientific community has sought to codify two basic principles in scientific research: (i) multidisciplinarity and (2) science dissemination. Both of these have been explored theoretically by various researchers over recent decades (Baracchini et al., 1996; Bracci et al., 1997; Mogorovich, Montanari, 1998), but they have found more concrete application in the European Commission's research funding programmes, beginning informally in Framework Programme 7 (FP7: 2007-2013) before being formalised in the Horizon 2020 programme (2014-2020). Snow (1959), whose own work spanned natural science and the humanities, decried the impossibility of communication between scientists and people of letters, and their resultant inability to collaborate with one another, suggesting that scientific research and technology are vital for a community's social development but that political decision-making was dominated by the humanities. Snow describes the unease of the intellectual when brought face to face with the clear separation that exists between scientific research and study of the humanities. More than the concern of the individual, however, he outlines the numerous problems of a political, environmental and cultural nature that this division might cause for society at the global level. As Collini (2009) has shown, the target of Snow's critique was the hyper-specialisation of the language used in different sectors, which acted as a break on the diffusion of scientific results and, as a secondary outcome, prevented non-scientists from writing and reflecting on scientific subjects. The Nature Editorial (2009) voices the need to make space for a third culture that can help bridge the yawning gap between the existing cultures of science and the humanities. For Brockman (1995), this third culture is not an academic discipline, but a process that needs to bring on board both those who "do" science and those others who work to further innovation in human thought.

Applied GIScience: the SECOA research project

In seeking a response to the numerous challenges posited by the issue of environmental conflict, the FP7-funded project "Solutions for Environmental Contrasts in Coastal Areas (SECOA)" brought together researchers from eight countries in Europe and Asia who worked in multiple disciplines in the social and natural sciences or engineering. The results of their research were developed into practical political proposals designed to help alleviate the effects of such conflicts. The data amassed during the data-collection phases relate to a combination of objective and subjective situations. What binds these heterogeneous threads is geographic localisation, insofar as for all their variety, they are all related to a specific territory. The georeferencing of each data point, which underpins TFL and each of its various interpretations and applications, also helps bring to light additional similarities and interpretive synergies. Including areas for study from both within and outside the EU lent additional significance to the results, but it also led to issues in terms of the comparability of data. Identifying the conflicts themselves was also a subjective matter, in the sense that they were selected on the basis of the decision to address at least one of the following areas: (i) economic development (industrial development, tourist industry, harbour restructuring, marina construction) vs. environmental protection (creation of protected areas); (ii) preservation of natural sites and biodiversity; (iii) competition for the use of resources between existing residents and newcomers, i.e. as a result of human mobility. As such, in addition to having to be localised along an area of coastline, the conflicts would have to be chosen in line with the SECOA project's needs in terms of comparability, and not for the purposes of illustrating, in statistical form, the needs that distinguished the surrounding metropolitan contexts in their entirety. It was also acknowledged that there was a need for local-level analysis, which would be defined in the following terms: (i) all the data collected by SECOA should be used regardless of their level of comparability; (ii) the pursuit of a truly cross-sectional comparison was discarded in favour of treating data in coherent "national" or "regional" divisions, beginning with a "longitudinal" analysis within the confines of each case study; (iii) data from different metropolitan areas were not compared directly; rather the areas themselves were compared after the data had been analysed and the relative issues and complexities had emerged; (iv) nor were the conflicts categorised in terms of "types" that could be easily identified and compared across the different metropolitan areas; rather they were entirely localised, geographically, together with their attendant issues, within the boundaries of each area; rather they were localised, geographically, together with their attendant issues, within the boundaries of each metropolitan area; (v) in this way, the conflicts were considered in relation to the territory to which they pertained, where they began and where they continued, i.e. in a tangible and non-abstract space; (vi) as such, each metropolitan area was understood as a "network of places": the place is a space of living, consuming and producing; it is the space of social relations and mobility. The place, so defined, is a social construction.

Given the availability of information and geographic data sets for the EU countries, it was decided to convert the relative data from vectors to raster-based GIS. The vector spatial data model defines space as a sequence of cells of the same dimensions that are organised in columns and rows, and composed of single or multiple bands. Each cell contains an "attribute" value and a set of location coordinates. Unlike a vector-based structure, raster coordinates are bound within a matrix. Groups of cells with the same values represent the same type of geographic characteristics. Having conducted tests on the available data, it was decided to use square 1×1 km cells. Each metropolitan area was represented using a variable number of cells (stretching from just a few to many miles), which meant it was more convenient to use the raster database for extrapolating the SOMs. Geography – and as such, GISys – operates on the basis of spatial analogies such as those alluded to by Tobler (1970); SOMs, as

Kohonen (1995) explains, use logical analogies.

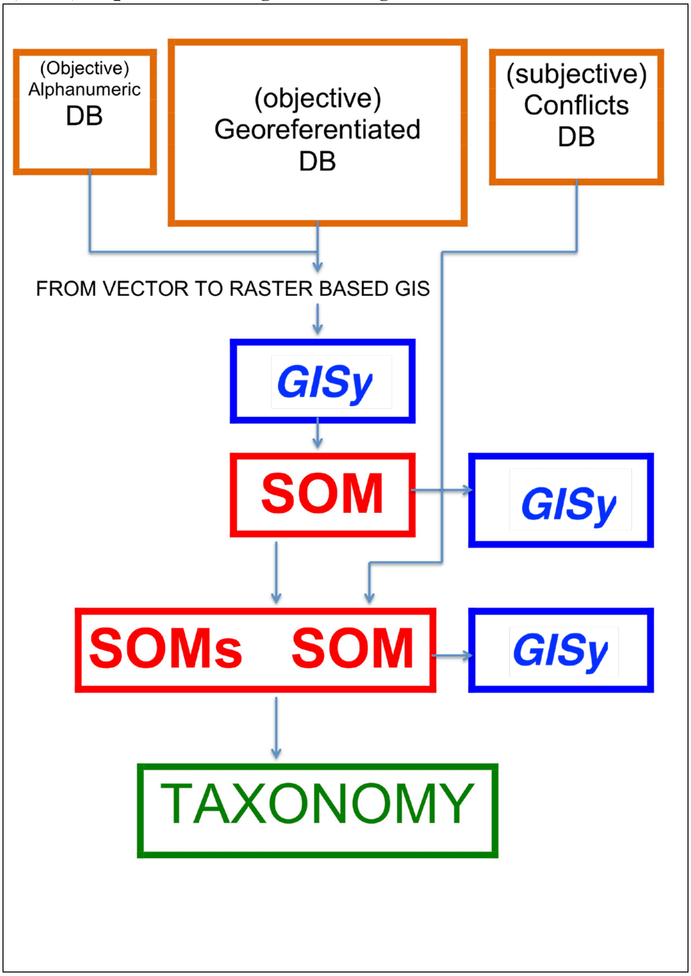

Figure 1. SECOA Geographic Information Science Logic Model

Organising the data in a GISy Database (fig. 1) facilitates a more manageable and comprehensive transposition of data to the SOM. Metropolitan areas can thus be structured according to a sequence of qualitative parameters, which are grouped in various ways. A further level of extrapolation, a SOM of SOMs, made it possible to identify eight types of situation affecting the metropolitan areas used as case studies. The data on the conflicts that were collected in the early phase of the project, meanwhile, were processed using an additional SOM, and led to the identification of five situation types. The SOMs, and the SOM of SOMs, were subjected to further processing using GISy instruments to make them more easily understandable by policy makers, end users and stakeholders.

Conclusions

Although contemporary society is the author of the pervasive use of ICT, and its most problematic consequences, it is also one of its victims. Many of our actions are monitored using algorithms that in turn nudge us towards certain behaviours, habits, choices and forms of consumption. Search engines are the primary mechanism that determines which information reaches an observer and the modes and hierarchies that are at play in the process. By these means, the user can be directed, and his or her culture shaped and choices manipulated. Above all, the aim is to convince the user that the information received from the search engine is consistently reliable, relevant and impartial. We thus return to the idiographic approach, which interprets the future within the limits of knowledge of the past. There is an oft-referenced algorithm that has been used in the United States for calculating the risk of criminal recidivism, whereby in the absence of a specific criminological rationale, data were processed on the basis of a correlation identified in an historical reference data series, namely that black people showed a greater propensity for crime that white people. The idiographic method is predicated on a non-univocal codification of the pursuit of what is, ultimately, an interpretative form of knowledge. It admits a plurality of methods and approaches, and the originality of interpretation engendered by the selection of reference documentation and contributing disciplines. The opposite is true of the nomothetic approach, which assumes an unequivocal codification of scientific research based on knowledge that is to be passed forward as a basis for future learning. Geography, if understood in its capacity for interpreting the phenomena that occur on a given territory, is a form of science. As such, it also has the capacity to act as mediator between different disciplines in a multidisciplinary approach. The third culture is not a discipline but a cultural approach that requires guidance through the judicious application of the science of geographic information.

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