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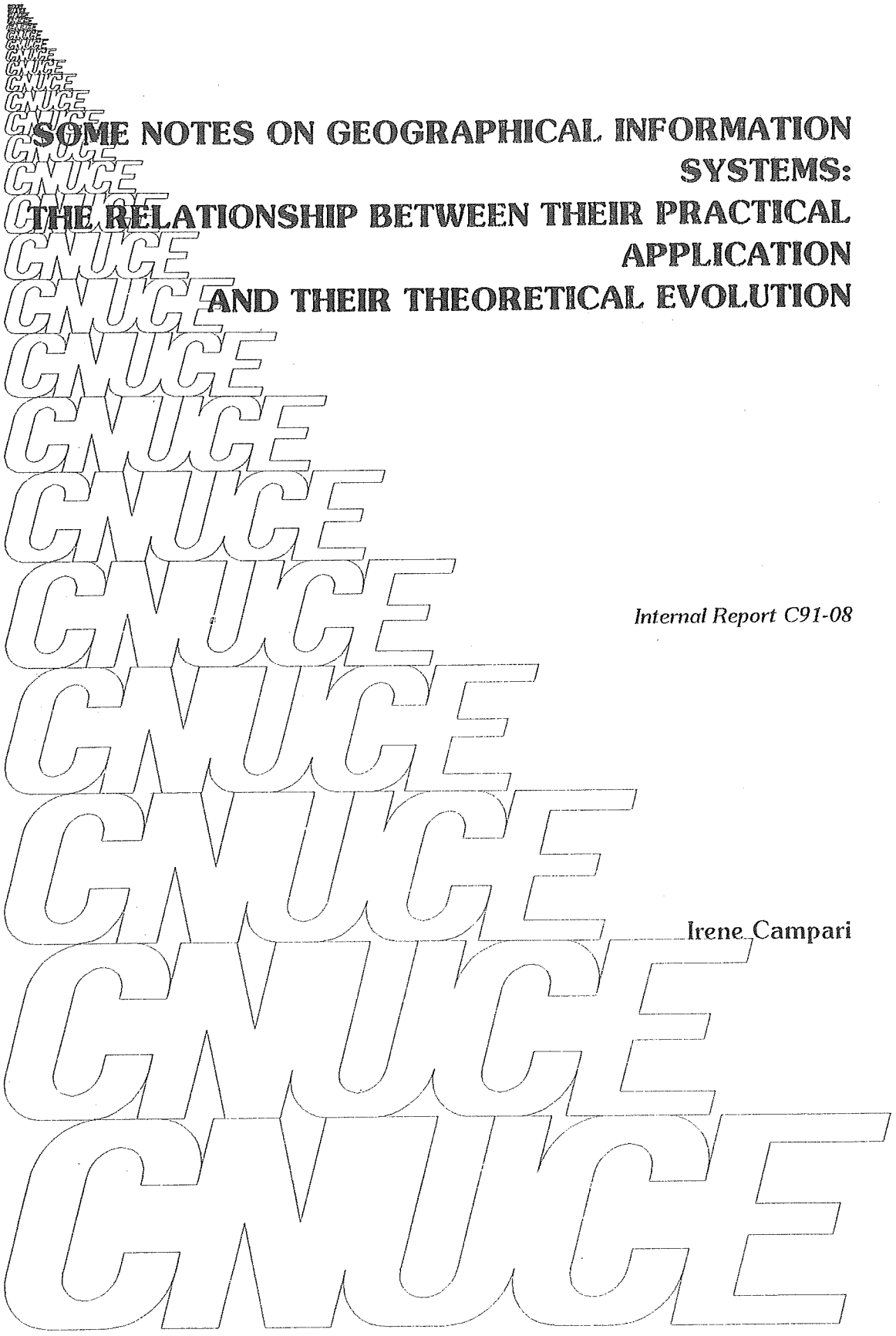

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Some notes on Geographical Information Systems. The relationship between their practical application and their theoretical evolution

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SOME NOTES ON GEOGRAPHICAL INFORMATION SYSTEMS: THE RELATIONSHIP BETWEEN THEIR PRACTICAL APPLICATION AND THEIR THEORETICAL EVOLUTION

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ABSTRACT. GISs have recently entered into a new course: after a period of technical refinement, they are now passing through a phase in which their theoretical-cultural foundations are being re-examined. A debate on the construction of a new theoretical basis for GISs, begun by a group of experts in the field, is now involving many new, as well as the long-standing scientific and technological aspects of this discipline. Among the new-comers now demostrating interest are the cognitive sciences. Efforts aimed at developing expert systems and user/interfaces have stimulated in-depth consideration of the cognitive implications of the whole of GIS activity. Linguistics, non-Euclidean geometry and topology are becoming objects of such interest that GISs may act as springboards for a science of spatial information. Parallel to these new approaches however, there remains the current, widespread and purely operative view of GIS utilization, which, perhaps for solely incidental reasons, is at odds with the never approaches.
The paper presents some considerations on the two ways of viewing and working with GISs. The author, basing notes on experience in the field, hopes that it will contribute to the understanding how the new courses and all the issues involved have come to be perceived by those far from where it has been set.

1. Introduction

The immediate practical usefulness of traditional GIS tools has contributed towards making some of the inadequacies in their theoretical base inoffensive, especially given the fact that these inadequacies have not limited their original primary function of generating maps. The peculiar nature of

GIS has also contributed to the slow realization of these short-comings and their consequences on what has to date been carried out, or attempted using these tools. In fact, during these last years work in the field has been directed at meeting the ever-increasing market demand for instruments for the rapid solution of limited, well-defined technical problems. Symptomatic of this approach, is the subordinate position which basic research in information science and the other disciplines involved have assumed in the development and application of current GISs.
Until now only opinions have been advanced as to what precisely occupies the pivotal position in which GIS function are rooted. Many of these opinions have been directed at justifying the many technical, pseudoscientific or scientific activities and investments, undertaken for and through GIS tools. Therefore those justifications regarded some aspects considered relevant and vindicatory for the adoption of GIS tools (i.e. attention to user, to some application, to technicism, etc.). They were however only that, justifications; and could not therefore furnish any more than schematic palimpsests for technical method orientation for traditional GIS tools. In the few cases which went beyond pure justification, the theoretical base for territorial-data-processing technology was formulated from the "pure" confluence of theories and practices originated in the single disciplines, or pseudo-disciplines, involved in cartographic applications.

The interdisciplinary nature of GIS, in both its internal structure and applicative outcomes, requires efforts to construct an adequate theoretical base which are comparable to the creation of a new discipline. At the moment there seems to be a return to the basic elements underlying the field and a demand for in-depth scientific study in the fundamental sectors responsible for software development and its conceptual frameworks.

The directives of this new, only recently and effectivly formulated indicated by the issues raised at the NATO meeting, have suggested a number of questions.

2. In search of a scientific method

The need to establish a scientific method in the context of GIS arose with as the need for greater scientific dignity for a sector whose usefulness was simply too immediate, and at the same time, with the considerable financial involvement

on the part of both the public and private sectors for the applications of traditional GIS tool. Personally, both aspects interest me (the tool, and the application, not to mention the theoretical consistency) and not being able to give priority to either, I am of the opinion that all the factors involved must be simultaneously provided for, when any form of technological re-assessment is undertaken, particularly considering that it is to take place at only a few years' distance from a massive market diffusion of the technology. I would like to emphasize this point because, as soon as the make-up of a new inter-discipline has been established, space may be made for a tacit form of discrimination which could in the future be used to determine, *a priori*, what constitutes scientific activity, and what does not. In this sort of process, it is quite likely that the fields of some application of GIS will fall once again within the realm of the non-scientific. The establishment of a scientific method must provide for the in-depth analysis of these aspects as well as others, while at the same time keeping in mind that in the field of geography, as well as others, there already are a number of basic theories in search of applications through GIS tool.

It looks as if the objectives of some recent theoretical research directives, are actualy headed toward the formulation of a more coherent scientific method for activities involving GISs, in a broad sense. The definition of "scientific method" seems correct to me, because all the conceptualizations and praxis which have come to constitute a tradition in the use of GIS tool, can be engaged. Organizing the efforts to renew GIS in this manner, all the positive aspects of the work done up to now can be conserved. Thus, the many activities initiated in the absence of clearly formulated theoretical premises (and often even of practical goals) should be reframed within the correct methodological context, rather than disavowed. By choosing to define a scientific method, we may take this anomaly, incorporate it into the current transitional process, and then carry on. Method is, in fact, constituted at the end of empirical experimentation (Morin, 1984). In this way a research approach leaves an inheritance of select methodological techniques and some forms of conceptualization which have contributed to its success.

The definition of scientific method has an other advantage: within its range the basic theories of the applications disciplines are present, simultaneously and to the same extent, as the theories discipline of the directly involved in the both logical and technical fulfilment of tools.

Therefore the scientific method for GIS inserts itself within a distinct tradition of research and study, whose of scientific premises it can appropriate; so starting to work at a high level of theoretical elaboration, controlling at the same time the degree of application obsolescence of which is sometimes imposed by technological constraints. The new scientific method shall involve, for instance, the theories applicable to geographical phenomena such as complexity theory (Le Moigne 1984; Morin 1984b; Zanetto 1988), systems theory (Chapman 1977), fractal theory (Mandelbrot 1982), catastrophies theory (Thom 1980). In this way the final object of technological interest, the territory, becomes as active a subject of method as the "space", while at the same time avoiding a gap that might be created between different interests involved with GIS - those who deal with its "theoretical object", space, and those having to do with its "temporal aspect", territory.

There are however certain distinctions which must be considered, not to discriminate, but in order to be able to clarify in what scientific methodological context applications and basic research in scientific method for GIS are to be inserted.

3. GIS and epistemology issues: concrete consideration

Efforts to bring some aspects of the disciplines of applications and a new approach to the logical structure of GIS tools towards the theoretical focal points solicited by a greater attention to young scientific research methods originating in computational science, specifically the cognitive sciences inserts itself in the context of scientific method. At this moment, this is a "natural" outcome of the debate concerning the scientific base of a discipline dealing with computer science.
We currently find ourselves in a period of definition of new epistemology; from the laws of nature we have passed on to statements of bounds and possibilities; from research on the universal order, we find ourselves studying chaos; from linear processes we have passed on to catastrophies theory, from scientific determinism, to positivism and then to possibilism, from mathematical certitude, to scientific uncertainty. Every scientific field has recently recognized that the scientific method, in order to be such, must open itself up to the age-old concepts of the humanities. On this theme, European and American scientific cultures are in the process of dialogue without vindictiveness or feeling of

inferiority on the part of either. One needs only think of Gregory Bateson (1976, 1989), Edgar Morin, Von Foerster (1980, 1982) and the theoreticians of the new epistemology (Atlan 1983; Maturana 1978 et al. 1985; Prigogine-Stengers 1979) and the scientific-philosophical current called "neoconnesionism".
In new epistemology some fields of computer science, such as Artificial Intelligence and Logic, play a fundamental role; above all, the aspects of these fields reconsidering the processes of human kowledge. Computer science fields and humanistic disciplines such as cognitive psychology and linguistics have found a very fertile common terrain for integrating their new and old experimental acquisitions. This common terrain constitues the cognitive science; within each of the above mentioned disciplines mantains its sovereignty.

The convergence between cognitive sciences and GISs, which had its debut in articles published in the eighties (Mark et al., 1986; Mark, 1987), would give that evolutionary approach a very current methodological character, that is, not dictated by the belief that a dutiful scientific method for GIS is unavoidable, but rather guided by the conviction that it is precisely this experimental practice which represents the future of GIS.
The cognitive sciences, which should have had primary roles in the development of cartography (Robinson 1984), have some conceptual and strategic points of natural interaction with the GIS field: the attention paid by GIS sectors to causes of uncertanty of basic spatial conceptualizations, to the qualitative character of spatial reasoning, to the cultural differentiation of GIS users having heavy consequences on the effective use of tools and so on. Whether the GIS field wants expert systems or optimization of human/GIS tool interaction as the final outcome, it must consider all these issues.
But there are other aspects of the relationship between GIS and cognitive science which are not altogether explicatory.
Cognitive sciences, despite their having a philosophical tradition thousands of years old, have grown on the crest of the wave of computational science. If it is true that computational sciences represent the search for all the computations necessary for various cognitive efforts (Pask 1976 ; Fodor 1979, Morin 1989), then the cognitive sciences have a practically unlimited range of action and experimentation. Hoping to map out the field of competence of GIS, they should become the framework for the computation necessary for spatial analysis and territorial knowledge, methodologically obtained by means of a conceptual framework adequate to the recent themes so dear to some sectors of the

cognitive sciences (value of metaphor, imagistics, different kinds of geometry tied to spatial human perception, etc.). There are different schools of scientists which tell us indirectly that the way is long and difficult. The more they explain their motives, the shriller will be their laments at the difference between that which GIS tools are at present, and that which computational spatial science wishes they were.

For example, the current GISs, produced "ready to roll", have achieved great success because, despite their complex appearance, they represent the results of a process of simplification and standardization of the relation man/territory carried out in a completely artificial environment. Paradoxically, this has been the main reason for both their commercial success and practical utility. Looking at GISs as that which they are now and have up to now been considered as being, that is, an international business, it is difficult to believe that the long experimentation times required in the cognitive sciences will be respected. These sciences are not at the moment of much help in resolving the problems in this field, but they do aid in defining them, and, in any case, as far as I know, simple solutions which are immediately and practically transformable into a final product, do not yet figure among the goals of cognitive science. The inter-relationship between GIS and cognitive science could also have important long-term implications. For example, will the topics left open for the time-being by the cognitive sciences, such as the images suggested by perception and formed by the mind (the mechanisms of which are as yet totally unknown), in turn become open questions in the field of GIS? or will they be dismissed by embracing only those parts which are the most understandably near current GIS, that is, the association between image and metaphor. Does this not seem like a form of operative reductionism aimed solely at giving a wider meaning to activities which revolve around GIS user interfaces?

In order to assure that the relationship between GIS and the cognitive sciences realizes its full potential, the latter should develop a scientifically broader perspective of GISs, such as might be provided by a new scientific method.

Applications to GIS of concepts deriving from the cognitive sciences have had, and continue to have limited diffusion. It is my considered opinion that much of the explanation for this stems from this process of selection and reduction of cognitive science to GIS. Their basic roles have themselves been exchanged. Is it not the sciences which should develop new conceptualizations from experimentation on the

interactions of man with machine during the use of GIS? And why is it that this has not yet come about, nor is it in the process of being undertaken? It is a personal opinion that this would be of little use, because through GIS a type of consciousness is reproduced which has very little to do with intimate human spatial perceptions, as will be seen later.
In order to avoid disequilibrium, the relationship must be reversed. Although this will certainly complicate, rather than simplify the problems, current GIS must be considered only one of the possible fields for experimentation in the cognitive sciences.
At a level closer to our current interests, there is the fact that, in the parlance and destiny of GIS, all these acquisitions are involved from the point of view of theory as well as applications. One should be able to find suitable unifying factors between this age-old quest to understand man's thought and the systems which process spatial data which, all things considered, have for the last few years been largely given over to large-scale business; a fact which has provoked a certain incompatibility between the objects which are, in theory, to be unified.(*)

4. The reality of GIS tools

A consideration which spontaneously comes to mind at the end of these first notes for reflection is in the form of a rhetorical question - everything is useful to GIS, but what is GIS useful for? There is an existing GIS reality and a population which uses them, some more correctly than others. I shall begin with a assumption based on the facts of what exactly GIS has been up to now and what it is becoming, paying particular attention to the private and public service facilities employees for whom GIS represents their "daily bread". I do not believe that it would be a reduction of the topic to take up a discussion of GIS, starting with the current reality and practice in the field. The GISs available

(*) The Piaget study used by psychologists as a sort of vade-mecum for the study of human spatial orientation, certainly has a justifiable current relevance to discussions and clarifications regarding approach to spatial representation through GIS. But I ask myself, however, if the descriptive uses to which Piaget's studies and school of thought are put is enough to justify recourse to them. Certainly a higher quality contribution would result if Piaget's work could be used on an analytical level as well, a level which should also be applied with regards to GIS.

on the market are used for the production of maps, thematic more often than topographic. It moreover seems that it is this function which has allowed GIS to spread rapidly into a large network of users. If we are still discussing GISs, it is precisely because there is a base of public and private agencies which have continually applied them to their originally projected function. This reality should certainly then not be underestimated considering the quantity of work aimed at rendering GISs usable, or the useful results stemming from it. In light of these affirmations, I would like to consider some issue advanced during the NATO seminars. The cognitive science are still involved.

Let's take the example of linguistics. Language is one expression of spatial cognition; every language expresses unique syntactic differences which, in turn express semantic differences in the perception of space. Often the use of linguistic metaphors in daily communication stimulates the recognition of one single, exploitable, "common cultural element", making possible the communication too. Given that the main interface between GIS and the user is language, the need was felt to create a interface language which was particular and appropriate to the culture of all those speaking a given language. In and of itself, this consideration is quite fascinating, I'd say, in a culturally sense. Furthermore, since interfaces have originated in English-speaking countries, who often seem to forget that in order to use GIS systems, or any advanced technology for that matter, non-English-speaking countries have had to learn and use English. This phenomenon is not restricted to particular intellectually or scientifically qualified environments, nor to those in which, despite the lack of these qualifications, the workers have set about learning just enough English in order to be able to read manuals and understand the commands which they must send the GIS system. For many workers in the territorial sector, at least in Italy a few years back, GISs represented their first contact with this language. In fact, GIS is so inextricably linked to English that many terms used in digitalized map-making can be translated accurately and succinctly, that is without a rather wordy cumbersome phrase, into Italian only with difficult, if at all. Many employees in the Italian public offices devoted to the administration and control of the territory have had to learn such typical GIS terms as "editing, sorting, generating, plotting, drawing, overlay," etc. Their meanings in everyday English remain more than likely a mystery, and it would therefore be impossible to adopt them into more generalized use. They do not enhance the user's ability to understand English and are

therefore for them part and parcel of GIS. I know that learning a language does not mean getting hold of the conceptual structure which that language expresses. But until now the GIS goal has not been to represent the cultural conceptual structure of space (i.e. sense of territoriality) but just pieces of territory characterized by some quantitative variables.

Recuperating the specific linguistic connotations of the Italian language in order to construct an GIS interface language more appropriate to its structure, as well as to the culture of the Italian space, might be considered a forced enterprise. In the Italian school system, English is taught as a foreign language, and recently its teaching has been instituted in the first years of elementary school as well. In many areas of Italy, however, children will be learning Italian in the same way that the will learn English - in school from books - because their everyday language, the one they use to express spatial perception and behaviour, is a local dialect, one of the hundreds of such dialects existing throughout Italy (thoroughness in such a discussion is difficult because its limits are not clear). The geography of language (Breton, 1976) informs us that national borders are the fundamental boundaries for the formation of a national language which will extend as far as the national culture and education. However a national language is quite different from the languages actually used by the population to express their particular and effectively different culture.

Concerning the current everyday reality of GIS, it would be enough to institute the process of standardization anxiously awaited for years. All that would be required in order to carry out the functions for which a GIS is acquired, is to adopt a standard terminology made up of a set of key words with unambiguous definitions. Despite the best intentions, this seemingly simple undertaking has not been done, no matter how willingly or unwillingly the process has been subjected to the linguistic constructs imposed by the various producers of GIS systems.

During a meeting on linguistic problems held at the NATO meeting, a number of curious considerations were expressed by computer scientists. They expressed the need to trace the linguistic archetype or archetypes of various languages with the aim of understanding how a particular perception of space, expressed through the language, has entered into a certain people's culture. The curiosity of this fact resides in the fact that it presumes the search for a differentiated archetype, when in fact the archetype is unified. De Santillana, working in the sixties on linguistic archetypes,

reconstructed the history of various myths common to the different populations throughout the world, specifically, those regarding the heavens, and built up a sort of planetary wayfinding by means of considerations of the archaic structure of time. It seems to me that this is a path beginning too far removed and, which has in any case already been traversed and has produced relevant results. However, there seems to be little else for us to do other than make careful note of them, especially considering our fields of competence. Knowledge of the discoveries made by De Santillana and Von Dechend (1983) and other authors are useful because they allow us to progress in our research with more current objectives in mind, in an arc of time some thousands of years nearer to us. The fact that the age of Pisces will give way to that of Aquarius does not have much of an effect upon us; our perception of time has changed, just as our perception of space. If four thousand years before Christ the planetary movements were determined by means of the knowledge of terrestrial space, now it is from planetary space that we regard terrestrial movements. Before long we will find the new archetypes in the technological terminology which at present is only a couple of decades old, transforming language of the Remote Sensing into the virtual interface for the representation of terrestrial territory.

5. The territory of GIS.

I have asked myself what sorts of territories are, in the ultimate analysis, most easily represented by GIS and what are the standard representations for these territories. The answer is official territories, those ratified by law; not those perceived by the people living there, but rather the myriad nations, regions, provinces and townships created by decree or other legal procedure. The agencies and institutions which can most easily afford GIS are most usually public research or administrative offices. The use to which public agencies put GIS is largely the cataloguing of the official territories under their jurisdiction, either by means of, or within a GIS. I do not think that the intentions of those who have promoted the wide spread use of commercial GIS were any different from what has actually come to pass, which is the standardized processing and recognition of territorial representations of standardized and recognized regions of land. Even the collection of territorial representations particular to certain nations, such as the

cadastral, for example, is official, established by law and carried out with the aim of taxation. What could be further from man's perception of space. In order to find the least resemblance to man's perception in these collections, one would have to look back to the days of the historical 19th century napoleonic cadastral collection, in which the ability of the draughtsman was given free rein in the coloring (Campari 1984) and pictorial descriptions of urban and agricultural plots of land.
On the other hand, the research institutes which utilize GIS for territorial representation base their work on the administrative divisions, because it is to these divisions that official data are referred. In this way a representation of the territory can be constructed without ever leaving the office. How much these differences actually count nowadays in our field is something which remains to be established. The inflex arching streets of medieval Italian towns have nothing in common with the roads of Porterville. Yet both are represented by means of the exact same geometric primitives, the same topological properties, the same colour set, and the same hierarchy of predefined relations among the elements which make up the urban network. In brief, whether it is the urban data for Cortona which is processed in California, or the data for Porterville processed in Tuscany, the results will be the same - an approximation of the reality with conceptual generalizations at a level which will necessarily eliminate any form of cultural identification. The real difference resides, instead, in the human-determined spatial relationships consequent to the layout of villages; this could be a main point of antropological interest, welcome in GIS field. But because the GIS future is not clear jet, I also ask myself if interests are directed at maintaining these differences in the handling of territorial information or if, in any event, the goal is to reduce them to supra-cultural common denominators through the contributions of the Geographical Information Science. In the latter case the doubt arises that we are not seeking cognitive or cultural support for GIS, but a forced interdisciplinary character in which roles can be determined for those disciplines generally little associated with computer science.

6. Geographers dealing with GIS.

Mention was made earlier of the role which current geographic theories could play in future cultural adaptations to GIS. At this time, however, new conceptualizations in

certain disciplines remain in the best of cases only fundamental theoretical points of departure for the renewal of consciousness. There is a certain difficulty in transferring new theoretical concepts to research methodology. Examples are numerous. The first article on complexity was written in 1947 by Warren Weaver, but it was only in the second half of the sixties that methodological discussion began referring to complexity as a subject or object for interdisciplinary study; geography followed even later. Systemic theory is even older: Chapman (1977) wrote a splendid work on geography aimed at this, but as far as I know, there have been very few studies or in-depth research based on his theories, and even less known still are the institutions in which research in this direction can be carried out with the necessary consensus. Despite all these theoretical fits, starts and interruptions, GIS technology has been continually utilized, largely because it has a precise referent, territory. Until new epistemological characteristics have been rendered explicit through effective research (also in the ecological sciences) it will remain difficult to justify efforts to advance a new scientific research method through the development of a technology whose supporters themselves relegate the very object of their study to a secondary position.

In order to accomplish this, not only must instruments be technically capable of following such a development, but there must above all be geographers available to carry it out. Actually, recently geographers involved with GIS have been occupied with megaprojects of (official) data acquisition and organization with the rather heroic ultimate goal of one day attaining real time GIS processing. Finding the logical link which joins the disparate national collections of territorial data is certainly not the job which a computer scientist would care to take on, but nor would a linguist, mathematician or statistician who has contributed to realising the heroic enterprise. Usually it is the geographer to whom this task falls, taking years and years to find, as we say in Italian, the hank's end in an often inextricable tangle. When this logical connection has at last been located scientifically and technically, his or her work has very little value because it is an integral part of the technical routine. As anyone who has been dealing with GIS for even a short time knows, in order to obtain any high-level performance the information base must be at least above a standard threshold level of accuracy, at least as far as data such as administrative boundaries, population figures etc. are concerned. Personal experience has taught me that

attaining a data base accuracy which surpasses the confines of a single nation takes between two to three years, and then only if the geographic areas considered are not excessively bureaucratized, in which case twice as long is needed, with all the consequences which this time period entails. I shall offer an example carried out in the Mediterranean area. A research project was undertaken for the development of a data base for several Mediterranean countries. Immediately problems arose whose solution would require months, if not years, of application. Portugal, for example, has two agencies for the collection of population census data, the Commisao Nacional do Ambiente and the Istituto Nacional de Estadistica. The data amassed by these two agencies are thematically afferent, that is to say, in order to construct a useful data base for the evaluation of environmental impact in a certain *distrito*, one must assemble the data from both. Furthermore, they both contain some of the same information, for example the results of the 1971-81 and 1951-61 censuses. During the early stages of a project of this type, the data from either source might seem equally reliable, and the choice of one or the other might be made with indifference. But it is soon discovered that the sources are not at all equivalent because the methods for administrative coding adopted by the two agencies are not in the least similar. They are in fact so different that arriving at the optimal methodology for reconstructing the reference territory for Portugal cannot be absolute, but must take into account the different paths chosen by the INE and the CNO in their data. The situation in Turkey is even worse. In order to establish a territorial structure for Turkey in which to enter the data, even only census data, one must work from original documents and then reconstruct by hand the current administrative situation, as well as the various changes brought about by the 1955 census (Campari 1990). In effect, build an appropriate data base from scratch. Faced with problems of this kind, which admittedly must be solved before the GIS even enters on the scene, but which at the same time are posed exclusively in function of the GIS, the geographer is supposed to be enthusiastic about the chance to broaden the understanding of complex space representation, if for no other reason than the fact that it frees him from the complications found only at lower levels.

Joking aside, it seems that at this point it is quite clear that difficult problems exist in the phases prior to the use of a GIS; problems which not only are still in need of solution, but which are not even being faced squarely. These problems also involve the time required for the

quantity and quality of work to bring concrete experience in the use of GISs to conclusion. It might be objected that once an experience of this kind has been finished, a final, ready-to-use product results. An assertion of the sort cannot however be fully upheld. There are innumerable factors concerning accuracy and uncertainty which render the actual use of GISs with wide ranges and in non-homogeneous areas far from a foregone conclusion.

Conclusion

The definition of scientific method in the GIS field will obviuosly take a long time and much competence. This activity must be rooted in a current context both theoretically and practical-operatively. Only in this manner can be confusion about goals and means avoided.

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