Geocognostics — A New Paradigm for Spatial Information?

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Abstract: For some time there has been an effort to bring together the scattered fragments of spatial information theory into a single, organised body of knowledge and theory. The state of this effort is first surveyed and many of the gaps and problems identified. Following this, a list of desired characteristics for a full theory is presented. Then, a new framework or paradigm which meets most of the desired characteristics is proposed. This new paradigm is coherent with previous work in bringing together spatial information theory, particular the efforts which have been recently labelled Naive Geography, but the proposed paradigm goes beyond the characteristics heretofore proposed. Some of the consequences of adopting the new paradigm are then discussed in the paper. The new paradigm integrates cognitive and geometric approaches to space, provides a framework for understanding the relationship between different data structures such as raster and vector, and situates much existing work with GIS into a well-defined sub-discipline of what might potentially be a much larger discipline.

Introduction

Work on spatial information theory has evolved over the past two decades from a focus on purely geometrical aspects of the theory to a more sustained interest in the cognitive dimensions of spatial information. Hence, for example, the work on geometry saw the development of vector topological data structures (Chrisman *et al.* 1992), which were incorporated into commercial software products. This work also led to the definition of key implementation problems related to such geometry, such as the determination of a point inside a polygon ("point-in-polygon"), the problem of finding the union of two sets of arcs ("overlay"), and the construction of corridors around existing objects ("buffer zones"). Work conducted in parallel during this era included the manipulation and analysis of digital satellite imagery acquired by new sensors placed into orbit, such as Landsat (Ehlers *et al.* 1989). The use of large raster images during this time reinforced work with raster data structures in digital mapping systems, resulting in increasing familiarity with the advantages of raster data structures for thematic mapping.

Furthermore, these divergent interests fed the long-standing debate about the relative usefulness and roles of the raster and vector data structures used in geographic information systems. This was certainly exacerbated, in part, by the existence of commercial software which incorporated one or the other of these data structures, in competition with each other. However, the situation was more complex, for spatial analysis (point-in-polygon, overlay and buffer zones) produced different results depending on the data structure used. Which data structure was "right"? The debate has been largely tabled, if not resolved, by considering each data structure to be simply a tool for data analysis, each useful for different kinds of data. Most commercial systems now include capabilities for manipulating both data structures, and for converting automatically from one structure to the other (note, however, that many of the conversion algorithms produce different results also - see van der Knaap 1992.)

Toward the end of the 1980's, a series of meetings which brought together linguists, psychologists, and computer scientists as well as geographers and surveying engineers was organised (Mark 1988; Frank *et al.* 1989; Frank and Mark 1992). The goal of these meetings was to exchange perceptions of space and identify a research agenda for exploring cognitive issues. Underlying these meetings was the idea that space may be far more structuring for cognition than had previously been thought (Talmy 1983; Lakoff 1987). Following these seminal meetings, a series of bi-annual meetings were organised under the name of COSIT, or Conference On Spatial Information Theory (Frank *et al.* 1992; Frank and Campari 1993; Frank and Kuhn 1995). Most recently, these meetings have attracted a broader base of scientists from fields such as artificial intelligence, psychology, economics, history, and anthropology.

Several groups have focussed on the problem of the acquisition of spatial information and the development and nature of cognitive or mental models of spatial information (Blades 1991; Tversky 1993; Hirtle *et al.* 1993; Kuipers 1978). It is now widely believed that humans construct mental models of the spaces in which they live. At one time, these models were believed to be similar to standard maps which were maintained in one's imagination and used to navigate by - now, however, most believe these cognitive models are structurally dissimilar to map representations on paper. For example, Montello (1993) reviewed scale dependencies which are present in psychological space, but absent in geographical space, indicating that cogntive models of space have a lot more structure than geometrical models. Tversky (1993) suggested that cognitive models of space may sometimes be collage-like — thematic overlays from different points of view — and sometimes directly spatial, such as when environments are simple or well-understood.

Other recent research within the realm of spatial information theory is concerned with the role of time. Many conceive of time as simply another extension dimension, similar in behaviour to those associated with space (e.g. Pigot and Hazelton 1992), or at least separable from space (e.g. Galton 1995). Once again, cognitive approaches appear to be more complex. From a cognitive point of view, we know that knowledge of space and time are inseparable. To take a couple of recent examples in the litterature, Hirtle *et al.* (1993) show how temporal sequences of recall and planning reveal cognitive structure, part of which is spatial and part of which is not. Amorim *et al.* (1995) presented results of experiments designed to test different modes of judging spatial locations. These experiments also reveal that temporality and spatial learning are inextricably linked. These studies, of which there have been many, again raise interesting, but difficult, questions. Should we ignore the cognitive issues and build spatial-temporal databases based purely on our geometrical knowledge? If we do so, we limit the applications of our systems to more complex problems as well as the ability of our systems to respond "intelligently" to human users.

Another area where cognitive issues become inextricably mixed with more geometric questions is the problem of data quality, uncertainty and error. Data quality has been defined as data which is "fit for use" (Goodchild 1989). This definition links the notion of quality to the use to which the data will be put, and hence to cognitive issues, since the use of data is always linked to cognition. Furthermore, boundary uncertainty is known to be linked to perception. The boundary between two regions of similar texture is a transition zone, but many applications force us to draw in a sharp boundary between two such zones. The uncertainty associated with the placement of the sharp line is related to the conceptual difficulties of defining the regions which must be separated (Edwards and Lowell 1996). Indeed, the whole problem of when the landscape should be represented as a continuous surface and when as a set of polygons and boundaries has not been resolved. To say that the answer depends on one's application is simply to displace the solution into the cognitive domain.

Finally, there are many other areas where theory is lacking. Spatial statistics is one example. Spatial statistics have been developed to evaluate data for a variety of questions, including the presence of spatial autocorrelation within large databases (Cliff and Ord 1981), the nature or errors, stationarity assumptions about means and variances (Getis 1993), and so on. The techniques used proceed, in general, by evaluating the database as an ensemble, globally, whereas there is increasing need to answer more local questions. Hence questions such as "Are polygons of type A found more frequently than they would be on average in the data set?" or "Does our model predict a spatial distribution compatible with strongly grouped data?" can be answered, while other types of questions ("Does this constitute a group?" or "What is the error associated with this interpolated value?") are not so easily addressed. Database design is also an area where cognitive issues play an important, if still poorly understood role. At what scales should map data to be presented? How do we obtain one map scale from another? These issues are addressed via map generalization, which has been plagued consistently by cognitive issues since its early days. Much of cartographic design is carried out by cartographic experts operating on the edge of artistic design, using aesthetic criteria as well as functional criteria related to the information to be visualized.

To date, little real work has been done to develop a single over-reaching theory that embraces both cognitive aspects of space and the more clearly defined geometric properties which have been studied much longer. However, based on the brief survey given above, it is possible to identify at least some of the major issues that a general theory of spatial information should address. It should provide

(1) a framework for combining geometric and cognitive aspects of space, embracing both formal geometric and topological approaches to space and cultural, linguistic and social models of space;

(2) a general theoretical structure linking models of space, data structures and limitations of the latter;

(3) a solid theory for local statistics and their relationship to global statistics, including the study of spatial pattern;

(4) a theory of error and data quality, including the role of aggregation and disaggregation in such a model;

(5) a basis for understanding the relationships between space and time, as they relate to the representation and use of land information and to the problem of reasoning about such information;

(6) links between interactivity in human/computer interface and simulated interactivity in spatial/temporal models.

What is desired is a general theory which will provide tools to understand and relate different sections of the theory to each other, and provide an overall methodology to handle the collection of problems in spatial information. This list is rather ambitious, but, as we hope to show, by changing our perspectives of the situation, we believe it is possible to build a theory framework which addresses most, if not all, of these problems.

A New Framework for Representing Large-Scale Space

In existing spatial information theory, space is believed to be structured according to two "opposing" principles: as fields, where data is structured as a function of location, or as objects, where data is structured as a function of entity (Goodchild 1989; Couclelis 1992). From this perspective, the vector data structure views space as a collection of objects in empty space, while the raster data structure represents space as a continuous field and space is everywhere "filled". It is recognized, however, that this displacement of the so-called raster-vector problem is not a true solution. Indeed, it is possible to use a raster data structure to represent discrete objects and a vector data structure such as a TIN to represent continuous fields. Some researchers (Goodchild 1989; Couclelis 1992) have pointed out that the object-field distinction raises interesting and profound questions about the nature of spatial data. Little progress has been achieved, however, beyond the stage of posing such questions (albeit a very important stage!).

In cognitive studies, space is structured in two (or more) ways - directly manipulable space and so-called "large-scale" space (Montello 1993). The latter is loosely defined as space beyond the scale of directly manipulable objects, and it corresponds to a cognitive construction, since large-scale space is "too big" to be directly perceived all at once. Montello suggests a somewhat different classification of psychological spaces — into figural, vista, environmental and geographical spaces. Figural space is projectively smaller than the body, and can be viewed "all at once". Vista space is projectively larger than the body, but can also be viewed "all at once". Environmental space is projectively larger than the body and surrounds it, and hence cannot be viewed without moving. Geographical space is projectively much larger than the body and cannot be apprehended, even with motion. It must be learned via maps or models which reduce the space to a figural space.

I propose to recast such a conceptualization of space into a new paradigm for spatial information in general, both geometric and cognitive. Instead of conceiving the world as a set of objects embedded in Euclidean three dimensional space, or as a lattice of changing attributes, I posit the existence of a *local* Euclidean space which can be apprehended directly and represented explicitly, and of a second, larger space which is a construct of the human mind. The existence of a large-scale space, which cannot be apprehended directly but which exists "out there" in the "real world" is implicit, but it is posited that the structure of this space is largely irrelevant to the context of managing spatial information. Instead, we shall focus our attention on those spaces which are knowable, the first of which is a *local*, figural space, and the second of which are what I shall call *geocognitive* spaces. The plural is used because different spaces may be constructed by different individuals, different groups of individuals or even by different mechanisms within the same individual.

Local space, also called *geometric* space, is flat, Euclidean and cartesian. This space is a mathematical construct which corresponds to our standard, geometric view of space. *Geocognitive* spaces, on the other hand, are constructed from two other kinds of entities. These we shall call *views* and *trajectories*. Views are sensorial fields, integrating either human perceptions directly (*raw views*) or extended human perceptions such as via cameras and other machine sensors (*virtual views*). Trajectories are either paths of direct human movement (*direct trajectories*), paths of machine sensors used to obtain views (*virtual trajectories*), or projected paths of human perception within some other space (*projected trajectories*). This shall be explained shortly. Neither views nor trajectories are spaces, nor indeed, spatial. Both may be interpreted as *sequences of events processed by the human brain.* In fact, trajectories need not involve any movement whatsoever. They represent simply the time-evolution of human awareness of the human's location and/or orientation (or projected location and/or orientation) with respect to different views. Geocognitive spaces are constructed from incremental views obtained along several trajectories, where views may involve any combination of sensorial (external) and mental (internal) information. Note that there is nothing linear about these spaces. As suggested by Tversky (1993), they are not directly representable; they are necessarily mosaics or collages of some sort.

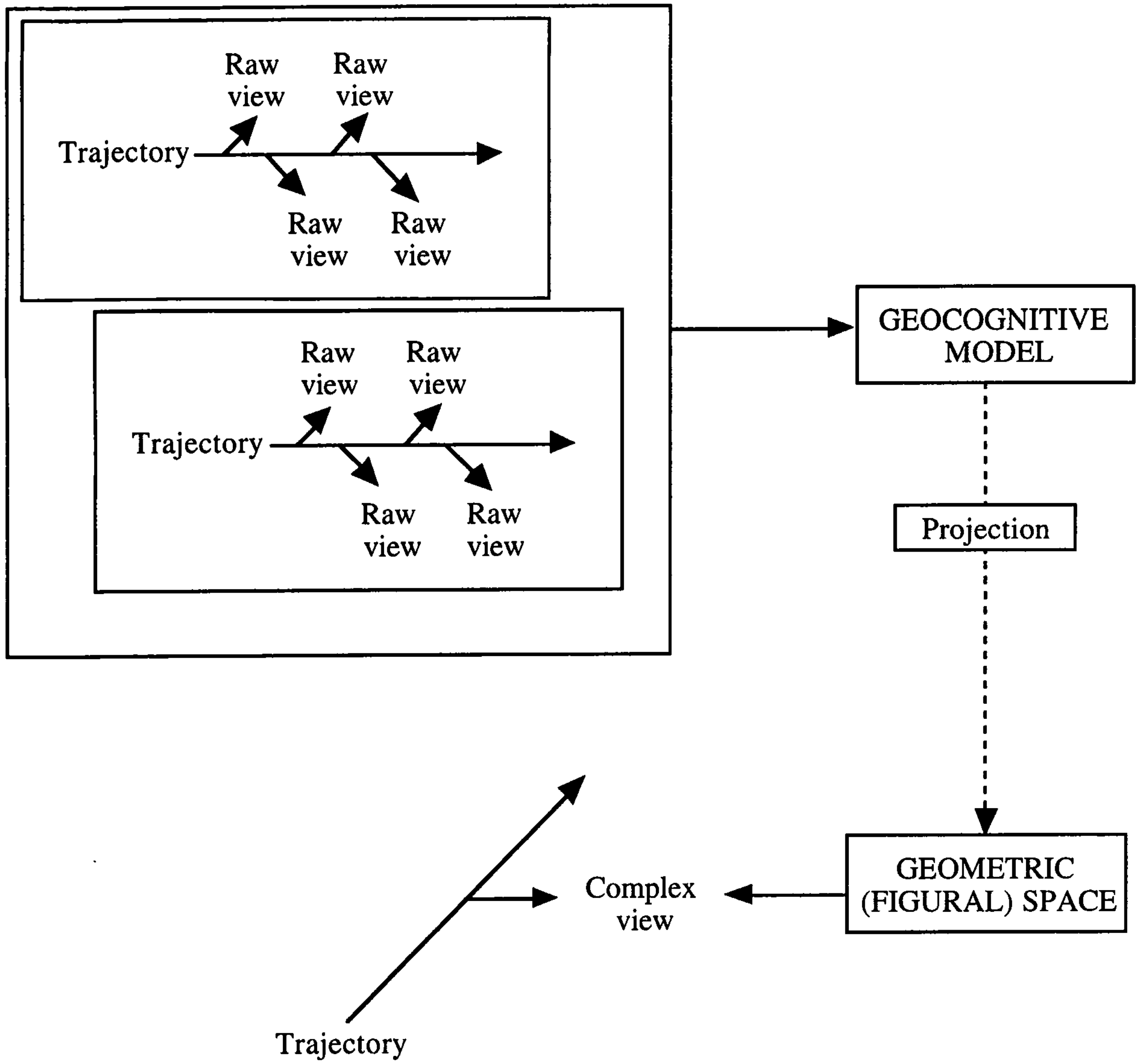

Figure 1: The structure of geocognitive spaces. Views of different types combine via trajectories to form such models. Parts of such spaces may also be represented with a figural geometric space and then viewed again, to form part of more complex geocognitive spaces.

Geocognitive spaces may contain modelled or inferred objects. Indeed, the definition of an *object* within this framework is that of a persistent construct which can be inferred from multiple, incremental views obtained along one or more trajectories. Note that objects are posited as belonging to the world of cognition, not to the so-called "real world". Indeed, within this paradigm, we say very little about the real world.

To continue developing the paradigm, *maps* are projections or representations of geocognitive spaces within local, geometric space (i.e. Montello's figural space). These projections usually involve extracting partial representations of the full geocognitive space. These representations will either be views or *traced* trajectories. Furthermore, maps, and indeed any local phenomena, must themselves be viewed. Figure 1 shows the relationships between the different concepts enumerated here.

Geocognitive spaces are constructed by linking views via trajectories. This is the process by which humans build "cognitive models" or "mental models" of the world. Geocognitive spaces may be projected, or viewed in many ways. Existing computer representations of space, such as the vector model of space, the raster model or other models, constitute such views. Indeed, Hirtle (1994) suggests that GIS may serve as a useful cognitive model of space, because it permits multiple representations of the same data and because it can be error tolerant. Remotely sensed images constructed out of mosaics are also views of a geocognitive space, since they are constructed from views using trajectories.

Geocognitive spaces contain hierarchical structure insofar as they use complex views constructed by projecting simpler geocognitive spaces onto geometric space. The level of nesting involved may be arbitrarily large. Hence, for example, a visual view obtained by a human without moving his or her head is actually a complex view, since it is constructed by eye movements (body part trajectories) and foveal view fields (eye fixations) combined together to form more complex views. Furthermore, each foveal view field is actually structured via photon events impacting the retina and being transmitted along the optic nerves to the brain. The internal structure of the resulting geocognitive space is already quite complex, and may involve memory-related distorsions, drug-induced effects, and so-forth. Furthermore, temporal information is almost always encoded into geocognitive spaces, although it may be supressed when views are obtained. Experiments with strobes and other artifices may reveal these hidden dimensions of the resulting spaces. Including head movements leads to another level of geocognitive space, with additional structures, and body movement again increases the complexity of the resulting spaces. Hence many levels of nesting of geocognitive spaces and views are possible.

It should be noted that the idea of trajectories and views has previously been proposed by Kuipers (1978; 1983) in his work on mental models of space for robot navigation. However, Kuipers did not extend the concept to spatial models in general. He used it as a mechanism for handling spatial information in the context of robot movement in a simple environment. Later approaches to the problem of robot navigation were more sophisticated, but to a large extent these incorporated or responded to Kuipers' idea. Hence, as well as rooted in cognitive concepts, these ideas may also be said to be rooted in the work of the AI community.

Implications of the New Paradigm

Implications for Geomatics and Geography

How does this framework or paradigm help us with the list of issues outlined in the introduction? First of all, let us examine the question of raster versus vector or field versus object. A map is now seen to be a view of a representation of a geocognitive space within local, geometric and figural space. Within the new paradigm, *the only hard lines which exist are representations of trajectories*. Views never have boundaries, because they are simply collections or aggregations of events. Trajectories are composed of lines, because the persistence of the perceiver (or his or her projection) during the latter's movement is a given. This casts a somewhat different light on vector data than we have had heretofore. It suggests that vector data are trajectories from which the temporal data have been deleted or thrown away. Let us look at a few examples in the light of this observation.

Cadastral boundaries, one of the early uses of vector maps, were originally constructed by "walking off" the boundaries of lots and noting the movements and landmarks used in the legal documents. Today, lasers and other devices are used to measure and locate cadastral boundaries, but these are also trajectories. Hence vector cadastral boundaries are indeed trajectories. In urban applications, buildings, roads, parking lots, etc. are all represented as vector outlines. However, here again the outlines represent either real or projected trajectories which humans have or can make. The so-called objects are actually derived from the fact that such trajectories can be carried out in a meaningful way. In forestry or soils mapping, the hard boundaries shown on the maps usually represent interpreter tracings from an aerial photograph. These are projected trajectories, where the interpreter projects his or her consciousness into his or her hand, navigating a path through perceived local differences in texture within the local space map which is the aerial photograph. Indeed, in general, *hard boundaries are introduced by trajectory tracing through local environments within locally-projected views*. Furthermore, trajectories are the result of a continual local decision-making process, whereby the perceiver selects a trajectory orientation which *balances* some set of variables extracted from local views, but which may be influenced by additional information stored in memory.

The new paradigm provides a framework for determining the limitations of existing data structures and hence when different data structures are appropriate to use. Hence, for example, because the vector data structure simulates trajectories but discards the temporal tagging associated with those trajectories, they are appropriate in contexts where objects can be defined by trajectories, where object persistence is the norm, where temporal tracking is not desired, and where cognitive loading of spatial relations is not important. Error models appropriate to the vector data structure include trajectory-based error models, such as outlined in Edwards (1994), and attribute-based error models (such as discussed by Goodchild *et al.* 1992).

An interest characteristic of the new paradigm is that the standard primitives of GIS are not present. We do not posit a point primitive, line primitive or polygon primitive. In fact, polygons do not have any direct existence at all — they are only regions of space "fenced in" by trajectories. Insofar as trajectories are linear, then lines are defined, and insofar as points may be viewed as events, they may be said to exist, although points are more like trajectories which involve no motion, and from which the temporal information has been excised. The new paradigm posits events and event collections (views) and trajectories as primitives, not points, lines, and polygons.

One of the more important areas impacted by the new paradigm is that of the theory of error in spatial data. Indeed, the new approach clearly distinguishes between so-called "boundary error" and so-called "attribute errors". We have already traced the origins of hard boundaries as tracings or projected trajectories within geometric space. Attributes, on the other hand, are abstracted representations of information present within views, i.e. they result from "clustering" view events according to some criterion. These two processes, clustering or aggregating view events and tracing trajectories through viewmaps, are fundamentally different. Each requires its own, distinct error model. Hence we cannot easily infer one kind of error from the other, without making many additional assumptions. Most of the work we do with spatial data exploits both aspects of spatial data, projected trajectories and view aggregates. In order to understand error and uncertainty in our data, therefore, we need to obtain error models for both kinds of process.

Furthermore, the new approach also offers a framework for understanding spatial interpolation. Interpolation becomes a kind of trajectory, where the balance requirement for choosing the trajectory orientation is based on maintaining a constant elevation (or a maximal gradient if tracing slopes). The determination of elevation is based on some arrangement of local view information. Different methods of interpolation use different methods of deciding how to construct appropriate local views. Also, spatial statistics is recast into an issue of the scales of aggregation of views.

Finally, work on data structures and algorithm complexity will need to be extended to deal with the more complex models based on nested hierarchies of views and trajectories which make up geocognitive space. In this way, the formal work on the implementation of geometry and topology capabilities within the computer will need to be linked to the cognitive studies and cognitive models much more closely than in the past.

Implications for Cognitive Science

Geocognitive spaces (so-called "large-scale spaces") are fundamentally cognitive within the new paradigm. The links between geocognitive spaces and local geometric spaces are clearly defined, although much work needs to be done to make explicit the details of these links (i.e. how are geocognitive spaces "projected" back onto geometrical ones?). One of the differences is that in geocognitive spaces, time and space are inextricably linked, whereas in geometric space, they are separable. Indeed, the paradigm suggests that the study of space-time as a whole is central to the problem of constructing a correct theory of spatial information. Another central difference is that the hierarchical nesting of views which is necessary to construct geocognitive spaces implies that scale is important, whereas in geometric space, scale is not pertinent.

Hence the new paradigm allows us the retain all of the richness of the cognitive work on scales of spaces and the roles of time and aggregation. The different classifications of spaces described by Montello may be constructed from our spaces, and in some cases we gain new insights. Hence, for example, manipulable spaces correspond to a geocognitive spaces constructed from raw views (mostly visual and tactile) and body part trajectories. Non-manipulable spaces require whole body trajectories to explore them. If no movement is involved, then the geocognitive spaces are entirely view determined. Furthermore, the geocognitive spaces constructed from one sense (sight, for example) may not have the same structure as the spaces constructed from a different sense (hearing, for example). They can only be compared directly by finding a representation mechanism within geometric space for each geocognitive space, with the disadvantage that the representation mechanisms will contribute to the comparisons.

The details of the construction of geocognitive spaces from trajectories and views need to be worked out. Much work in this direction has already been done. Indeed, the mental construction of objects out of different views is one of the central problems of both cognition and computer vision. The new paradigm may help sort out the central issues, however, and help focus the research over the coming years. In particular, the new paradigm suggests that models of geocognitive spaces could and probably should be constructed and represented on computers. The study of how this can be done, and the different properties different geocognitive spaces might have is likely to be a fruitful project for many years to come.

The geocognitive paradigm posits that large-scale space is constructed from views via trajectories. Views however may be emotionally or culturally loaded - they are not neutral perceptions of the world. Local space may be purely mathematical, but geocognitive spaces are not. Furthermore, geocognitive spaces will involve complex combinations of different cultural and emotional loadings. Since no external large-scale space is addressed directly by the new paradigm (i.e. we are not concerned with any "real" large-scale space), then geocognitive spaces must be viewed as *always* carrying a cultural loading, even if this is set to neutral. Any map of large-scale space will therefore contain such loadings implicitly.

Within the new paradigm, wayfinding becomes one of the key study areas which can be used to probe the relationship between trajectories, views, geometric space and geocognitive spaces. Within the new paradigm, however, wayfinding is no longer an activity of "tracing" or "navigating" large-scale space, but rather it is part of the process of "constructing" geocognitive spaces. This is not incompatible with many existing approaches within cognitive science, but the paradigm of geocognostics reinforces the central role of cognition in the entire process.

The questions related to human/computer interface may also be addressed using a similar theoretical framework as that used for building spatial-temporal databases. The roles of trajectories and views are likely to be central to both processes. The issues of map generalisation also need to be understood in terms of the scale dependencies inherent in the structure of geocognitive space and spaces, and in terms of the roles played by views and trajectories, which help cast light on how scale becomes embedded in such geocognitive spaces. Finally, spatial analysis might be recast within the framework offered by the new paradigm. Spatial-temporal analysis should focus on the relationships between views and trajectories, and on the mapping of geocognitive spaces back onto geometric spaces. Work also needs to be done on understanding the relevance of purely geometric algorithms to geocognitive spaces.

Summary and Conclusions

We began with an overview of the development of spatial information theory and many of the difficulties encountered in its development. We then proposed a list of issues which a complete theory of spatial information should address. These issues include stronger links between geometric and cognitive aspects of spatial information theory, a better understanding of the role of time and of the relationships between different data structures, the development of error models and other related questions. Following this, we proposed a new paradigm which may provide a unified framework for addressing these issues. The new paradigm gives cognition a central role, and exploits the interconnectedness of time and space within cognition to cast light onto many of the basic problems of spatial information theory.

The new paradigm posits two kinds of space - local, geometric space and large-scale, geocognitive space. Geocognitive spaces are non-linear spaces which are built out of multiple views of the world linked by human trajectories, real or virtual. They cannot be directly represented in map form, but they can be transformed, projected, or represented partially within local, geometric space. Views are collections of space-time perceptual events which may or may not be directly representable within local, geometric space. Trajectories are ordered sequences of space-time events associated with a perceiver whose temporal persistence is assumed. Objects are concepts inferred from multiple views which display incremental changes over small trajectories and their persistence is inferred from repeated trajectories. No direct statement about the real world is made - we are essentially concerned with our perceptions of the world, not with the world itself. Hence, within this paradigm, large-scale space is necessarily cognitive.

The new view of space carries many advantages. First of all, it presents a coherent view of space which can serve a framework for thinking about space, casting light on many areas of spatial information theory which have heretofore been fragmented and difficult to compare. Secondly, this new view challenges existing ways of thinking about spatial data. This is an advantage, because it is through such fundamental shifts in thinking that new theory emerges. Third, the paradigm gives cognition a central role, instead of one on the periphery of spatial information theory. Fourth, the paradigm helps us to see the importance of the temporal dimension in developing an adequate theory of spatial information. Fifth, the paradigm is compatible with the study of so-called "Naive Geography", a call to arms at the most recent Conference on Spatial Information Theory (Egenhofer and Mark 1995). Sixth, the paradigm casts light on several difficult problems within spatial information theory, including the development of spatial-temporal analysis capabilities, error models, spatial statistics, qualitative spatial analysis, formal representations of spatial theory, topology, data structures and models of space. Seventh, the paradigm allows us to recuperate much existing theory, although the theory won't always be viewed in the same way. It especially provides a framework which encapsulates much of the richness found in cognitive studies to date.

Weaknesses of the new paradigm include a still poorly defined role for spatial statistics and a lack of details indicating how geocognitive spaces can be constructed and how they can be projected onto local, geometric space. Indeed, the theory is not fully developed - only the bare bones exist. Hence there is material for study by cognitive scientists, computer scientists, geographers and geomaticians and indeed many others who might wish to participate.

We have called these new ideas a paradigm. Kuhn (1962) defines a paradigm as "a scientific achievement" which "is sufficiently unprecedented to attract an enduring group of adherents away from competing modes of scientific activity ... and sufficiently open-ended to leave all sorts of problems for the redefined group of practitioners to resolve". According to Kuhn, a paradigm serves to define implicitly "the legitimate problems and methods of a research field for succeeding generations of practitioners". In his now classic work on scientific revolutions, he studied the process of paradigm change within science. Somewhat lesser known, however, are his comments on the emergence of a paradigm within a new field, where no such paradigm existed before. Spatial Information Theory is just such a new field. At the recent COSIT conference in Austria, I was asked to participate in a discussion held around the topic of whether or not Spatial Information Theory can be considered a discipline. My conclusions at the time were that Spatial Information Theory is not coherent enough to serve as the basis of a discipline. In Kuhn's framework, it lacks a central paradigm. It is the fleshing out of such a central paradigm which forms the basis of a discipline.

It is my hope that the ideas represented in this paper, drawn as they are from many of the ideas which are currently circulating, but bringing them together in a new way, may help to provide the kernel for such a central paradigm.

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