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Geographic Information Science and Systems: A case of the wrong metaphor

by

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Abstract

The breadth of the subject material of spatial or geographical information science has been articulated in a number of places, but it is argued here that efforts to address the broad ontological and methodological issues have been mis-guided. This has led to a number of questions as to the appropriateness of the subject area as either a coherent science, or as a science at all. This paper reviews some of these statements, and argues that the recently proposed metaphor of a continuum between the extremes of science and system is wrongly inspired. It is argued that the continuum concept arises from the ability of people to locate and identify *themselves* in terms of the end-points and the continuum. An alternative relationship between the system and the science can be seen as a cycle involving the crucial processes of concept development, implementation, testing and revision. It is therefore seen that a critical use of Geographical Information Systems fits with a number of ideas of the nature of science in general and the advancement of scientific knowledge in particular. The argument presented here, therefore supports the study and development of GIS (whichever meaning is ascribed to the acronym) as part of a scientific endeavour. Two further consequences follow from the discussion. First, it reaffirms the frequent assertion that education must focus on spatial theory, as opposed to training (which is specific to one or more systems). Second, the use of systems is an important stage in the development of spatial theory, providing a testing ground for that theory, and, furthermore, because all theory is a state of knowledge at a particular time, which becomes embodied within a system, use of the system should always be informed by a critical understanding of that theory.

Introduction

Recently it has been suggested that those working in Geographical or Spatial Information Science should pay some attention to the intellectual basis of their research in general, and how it fits with ideas about scientific endeavour in general. Discussion, which has centered around whether GIS is a collection of software items gathered into a system composing a tool (Taylor and Johnston, 1995), or is a coherent field of scientific endeavour in its own right (Goodchild, 1992) has abounded in the last few years. This discussion has come from two different areas: from geographers concerned about the use and attitude to the broader discipline (Jordan, 1988; Pickles, 1995), and from practitioners of GIS, who, it must be admitted, have a vested interest in the outcome of any such discussion (Goodchild, 1992, Openshaw, 1997; as has the current author). The discussion has also arisen in at least two academic disciplines, amongst geographers (Pickles, 1995) and archaeologists (Tilley, 1994; Wheatley, 1993.) generally with those using and developing GIS on one side of the discussion, and others in the disciplines on the other side. It should be noted that the argument has by-passed many geographers and archaeologists, both those using and not using GIS. The discussion has been characterised by the slinging of metaphorical brickbats (Pickles, 1995) and return salvos (Openshaw, 1997; Unwin, 1996), by assertion (pointed out by Openshaw, 1997) and counter assertion (see those in Openshaw, 1997). Better-tempered discussion has also been presented (Wright et al., 1997; Flowerdew, 1998), but some has been met by debunking polemic (Pickles 1997). Among those engaging in the discussion views are becoming entrenched, in spite of the fact that dialog is also occurring (Sheppard and Poiker, 1996).

To other disciplines involved in GIS endeavours there may not be so much discussion and problem. The scientific basis of the work being done needs to be articulated, and in any disciplinary area it is necessary for those doing the working to have access to some of the concepts of the philosophy of the science they understand themselves to be doing. This paper therefore attempts to cast further theoretical light on the mists of GIS from an interpretation of some writings in the philosophy of science.

The paper first reviews a recently presented model, which is a specific motivation for the cogitation that has led to the ideas presented here. It goes on to examine an alternative model of advancement and development in the discipline. Some implications of that model are subsequently explored.

The GI Continuum

The prevalent model of the scientific position of GIS is the continuum between Geographical Information Science (GI Science) at one pole and Geographical Information Systems (GI Systems) at the other (Figure 1). This simple model is proposed and discussed in a paper by Wright et al. (1997) arising from a discussion on an electronic mail list (GIS-L). The construction is, however, theoretically problematic, as suggested by Pickles (1997), but for different reasons. The model results in polarisation of the subject material. Among other things, it implies that:

- users of a GI System cannot be indulging in a valid scientific endeavour unless it is in the scientific domain of their subject; and
- the unthinking use of a system by a soil scientist may be doing good soil science, but never doing more than using spatial science.

This seems extremely unsatisfactory, and below I argue that such uncritical use of a GI System is not good science in any sense. Furthermore, as we will see in the following discussion, this model has no explanatory power as to how either GI Science or Systems develop.

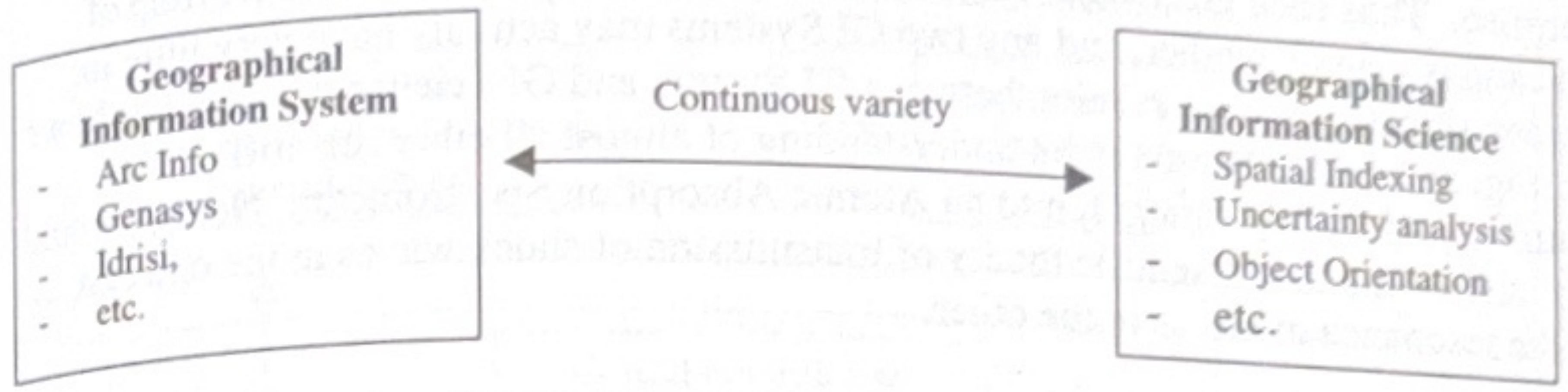

Figure 1. The continuum between GI System and GI Science

A quick consideration suggests that this continuum model has more to do with how people use, develop and employ GIS (in both the Science and the System sense; GISS henceforth). Neither the user nor the theorist of spatial information is necessarily an exclusive specialisation (Figure 2). Many individuals both employ extant commercial GIS (as black boxes) and can and do develop new and interesting spatial theory, which may employ development of source code because no GIS can be used as a vehicle for implementation of the novel concepts developed. It is therefore reasonable for a person's contribution to and use of GISS to lie on a continuum from pure development of theory to extensive system use. As a result they can realistically consider what the style of their participation in the GIS project as either technology or theory development. Indeed, as Wright et al. (1997) document, the primary evidence for their model is personal statements made on an electronic listserver. Those authors took care to establish that the contributions did reflect the persisting ideas of the writers, but such statements are not necessarily well informed by more than opinion rather than critical reading, or understanding of the issues, in this case the philosophy of science.

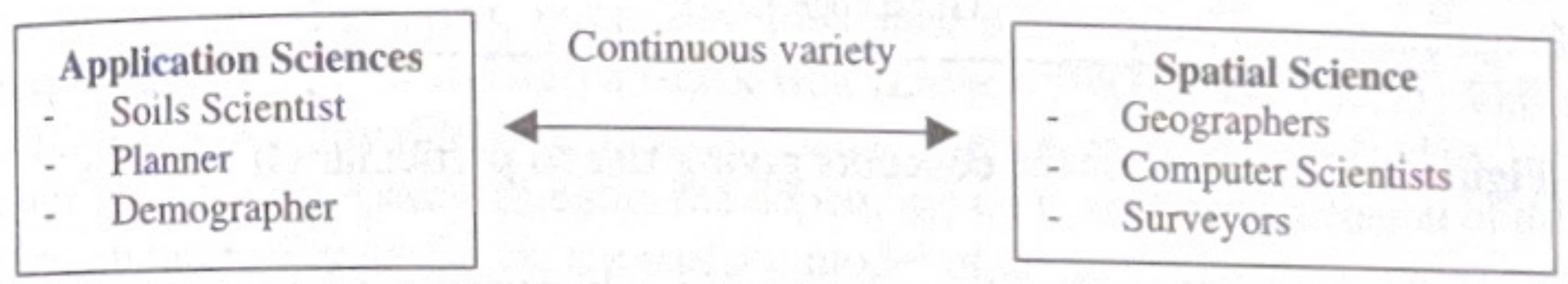

Figure 2. The Geographical Information Continuum of Projects and People

I believe therefore that the Continuum concept describes people well, *but not the science*. Another metaphor is needed to help us understand the much more complex interaction of theory, system and application.

The Cycle of Geographic Information Concepts

An alternative basis for exploring the interactions of GI Systems and GI Science is that of the theory underlying the tool and the tool itself. Thus the Tool, a particular GI System is no more than the realisation at a particular time of some of the concepts of GI Science. Thus the GI System is a black box (in the sense of Latour, 1987), being the implementation of the spatial concepts developed within the GI Science. No GI System embodies all the concepts of GI Science, rather any particular GI System implements only a subset which is identified as appropriate by the system developers in collaboration with some potential group of users (sometimes one and the same people). Many concepts in the science are experimental or of dubious practical value, and they may not be seen as being marketable and so a useful part of a system which is mainly a commercial enterprise. Thus each GI System can be more suited to one application or a group of applications than to another, and any two GI Systems may actually have very little in common (Figure 3). This relation between GI System and GI Science can also be shown as in Figure 4, and is based on the understanding of almost all other scientific instruments, from a Seismograph to an Atomic Absorption Spectrometer. Neither would exist without the hard scientific theory of transmission of shock waves in the one case and the resonance of atoms in the other.

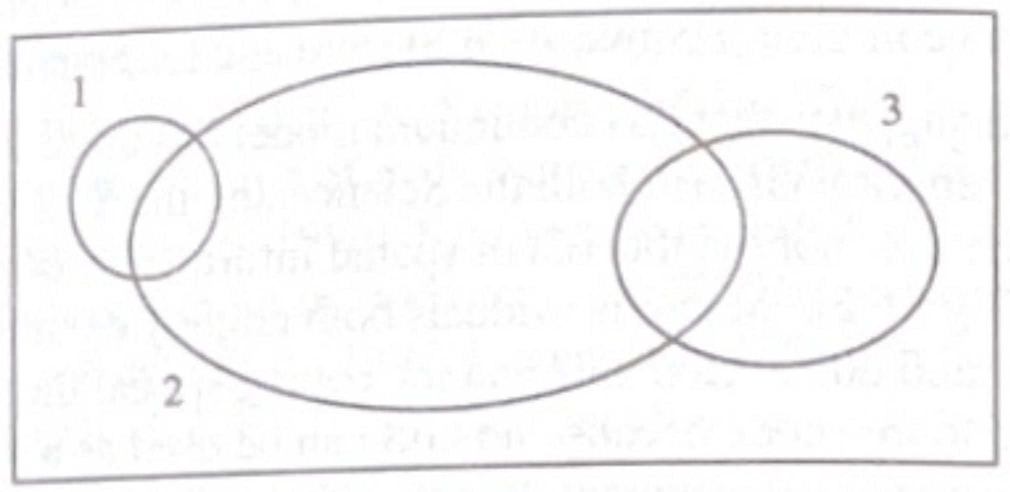

Figure 3. The differing spatial concepts that may be implemented in GI Systems 1, 2 and 3.

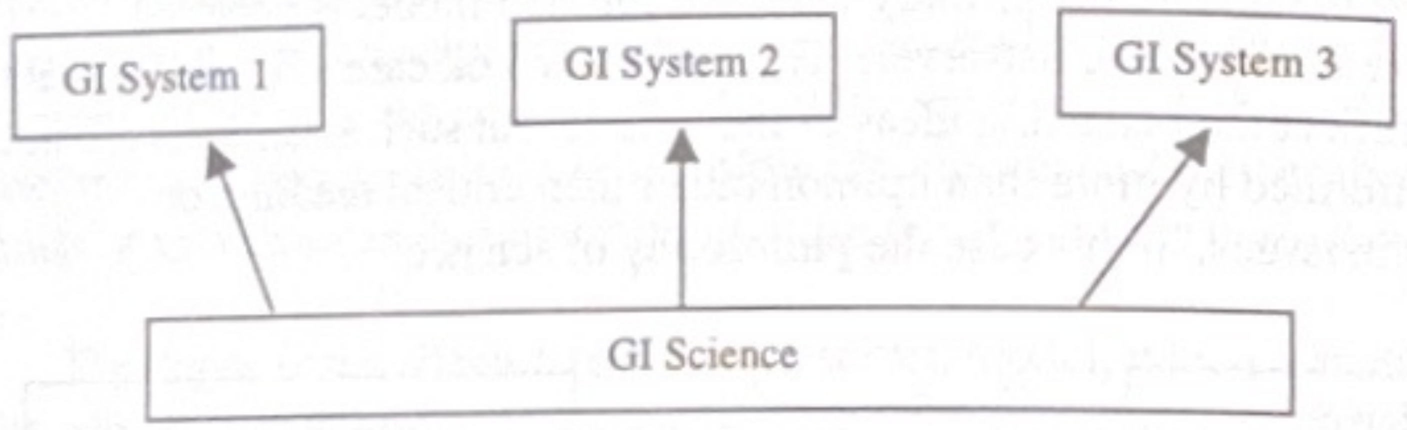

Figure 4. GI Science as the concepts giving rise to particular GI Systems

System and Science have another relationship, a bi-cyclic model shown in Figure 5. Many people will recognise the lower cycle of GI Science. Here we can see the development of concepts resulting from the critical valuation of existing ideas through publication and critique in the scientific literature, and resulting in the development of new concepts. This is similar to the critical rationalist approach articulated by Popper (1972), and can be seen as the essence of spatial science and spatial theory, criticised though it has been in a number of publications from social theory as disembodied and denatured (Pickles, 1995; Tilley, 1994). The criticism is that any method should be specific to data, and can only have any meaning in a particular context.

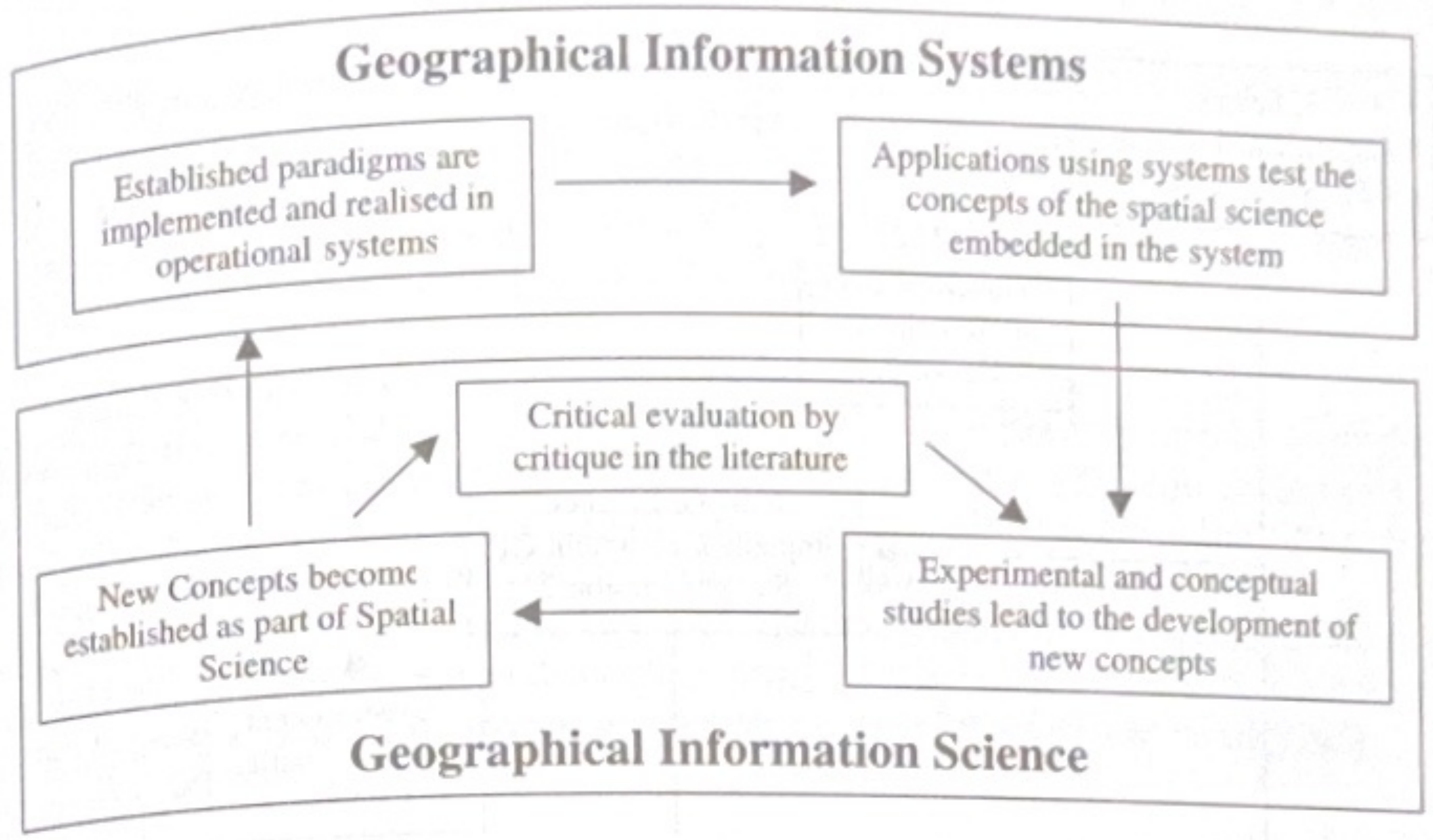

Figure 5. The GI Science-System cycle

As a personal view, with which others may agree or disagree, this author takes exception with the full critical rationalist and wider positivist epistemology, since I believe that changes in spatial concepts, as a result of the critical writings, are not necessarily nearer to any truth. Rather the set of concepts in spatial science at any one time is a set of ideas of how spatial phenomena may be described from our experience and scientific understanding of the world, whether as a soil scientist, a demographer or as a member of the public. That being the case, there is always scope for revising the concepts as a result of criticism, and to develop a new statement of understanding. Such a statement can be transformed into a Black Box (Latour, 1987): a GI System. This cycle can be illustrated in many different areas of spatial science, and can even lead to alternative models of the same phenomena depending on the conceptualisation of the data by the investigator. For example, the surface model of demographic data is held by some to be a superior model for the distribution of human populations, while others continue to analyse discrete spatial units (Martin, 1997).

As well as the lower conceptual loop, Figure 5 shows an upper loop through the GI System. Because GI Systems are a realisation of a particular set of spatial concepts at a particular time, this loop shows that users of GI Systems make use of the concepts in their applications. Therefore they are in a position to critically evaluate the concepts embedded in the system in use in the context of the application. Since the concepts at any one time are only a state of understanding, they may or may not work well for a particular application. If they fit well then the user of the system can provide valuable feed back and critical valuation of the concepts embedded. If the concepts do not fit well then the critical evaluation is equally valid and helpful to spatial theorists and system developers. Interestingly, since the concepts can only ever be considered transitory, of some unspecified duration, no application can ever be '*good*' science, even in the application domain (whatever it is; forestry, business, or whatever) unless the critical

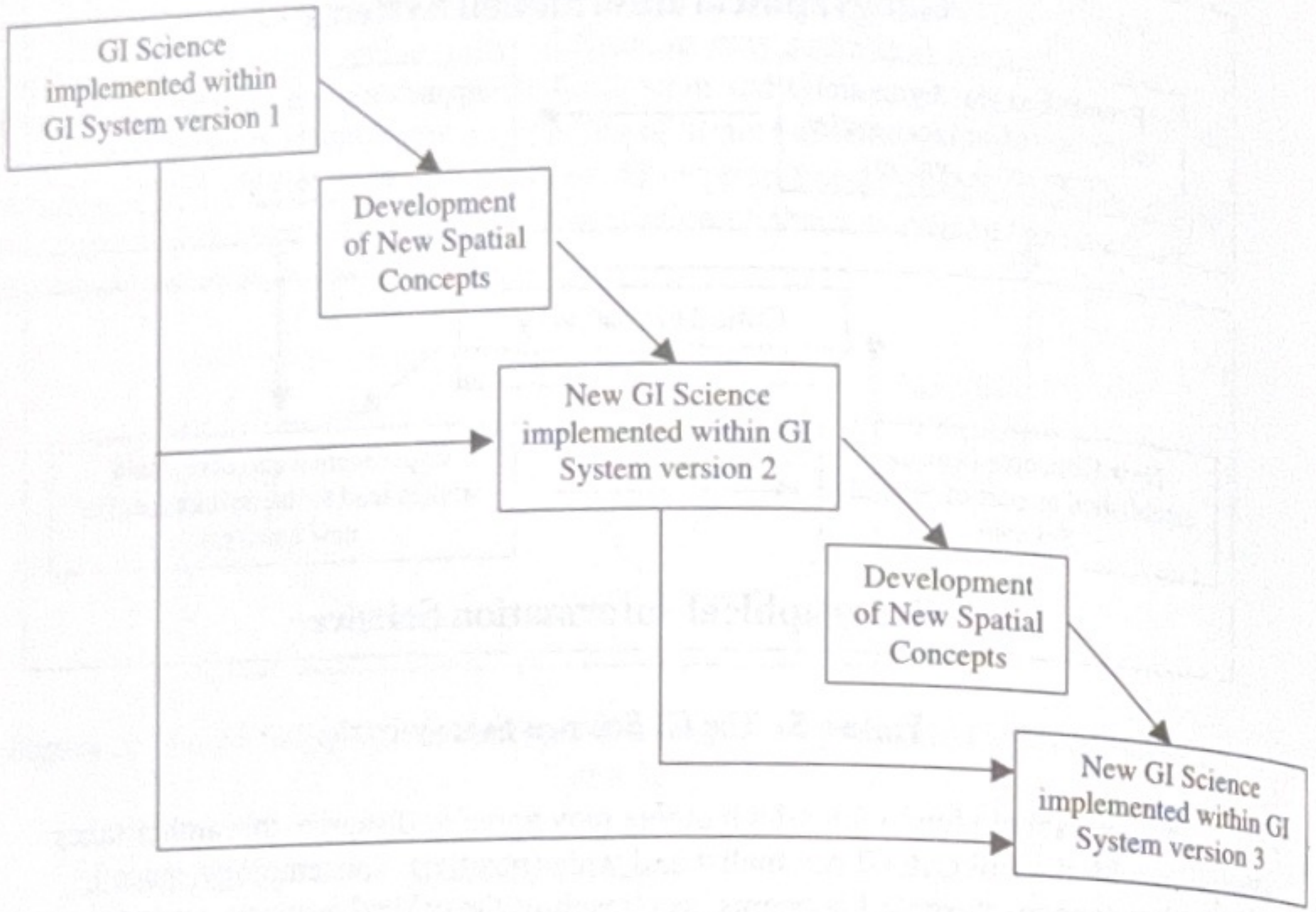

Figure 6. The cascading and incremental development of GI Systems as software versions

evaluation of spatial concepts is part of the application. If a poor fit is encountered then the application should at least be treated with circumspection, if not rejected.

Furthermore, in this model of development, we can clearly see that ideas may cycle within GI Science being honed and developed before they are incorporated within systems. Examples of this abound within the research and implementation history of GISS, and include error handling which is now emerging from the research community into the systems, as is object-oriented data modelling.

Some concepts may legitimately reach a level of longevity, and a period over which the majority of practitioners do not evaluate those concepts such that they may be considered paradigms in the sense of Kuhn (1970). Fisher (1996) has listed a number of GI Science concepts implemented within GI Systems which may be considered paradigms, including the paradigms of the Boolean map, the layer-based raster or vector models, the metrics of space, cartography, and the image.

Versioning and Specialisation of GI Systems

Software draws on many different concepts, including user-interface design, functionality, and data structures. Concepts from the domain (GI Science, in the present case) are fused with general ideas from computing systems, and changes in either may lead to changes in software versions. All commercial software goes through numbered

versions. Typically the first release version of a particular software package is numbered 1, with small amendments (bug fixes, small increments in functionality, etc.) resulting in versions 1.1, 1.2, etc. A major revision to the software is characterised by changes from version 1 to 2 to 3 etc. This principle is true of all software, and the procedure is used in the development of public domain as well as commercial software.

Figure 6 describes the transition in concepts through versions, and the introduction of new spatial concepts can be seen. Each subsequent version draws on the concepts embedded in earlier versions, but as time passes, and by the time of version 3, for example, the influence of version 1 will be less than in the implementation of version 2, because of the concepts embedded in version 2. This means that over time the software version can be unrecognisable from its earliest realisation, and the situation may even be reached when concepts embedded in version 1 may be re-introduced in a later version, but this is unlikely to happen in practice, because later versions usually only enhance the existing functionality.

Some of the larger GI Systems are being marketed in specialised variants. Development of these involves sub-setting the overall functionality of the complete system, to isolate those functions relevant to a particular application. This process of specialisation is depicted in Figure 6. Change within systems without changes in the science is tinkering in the sense of the science, but it may produce useful changes in terms of usability and usefulness.

Versioning of Concepts

While I have argued that there is a set of concepts, which we can recognize as those of a GI Science, it is also the case that scientists working in different areas of application develop their own spatial science. Furthermore, those working in a particular area find only a certain subset of all spatial concepts useful in that area of application. Therefore, there are effectively as many different GI Sciences as there are groups contributing to the development of spatial concepts and some of these are known to very few people in the wider GI Science community. Those working in one sub-area may develop concepts to a considerable and advanced level before a wider community adopts them. The development of regionalised variable theory and Kriging is an example of such a conceptualization of space, and development of related methods, first in the mineral prospecting community and subsequently in soil science, before adoption by an increasing community of spatial scientists.

A number of alternative diagrams to illustrate this history of development can be envisaged, but the most obvious is based on a time series of Venn diagrams, each a snapshot. Two contrived examples are shown in Figures 6A and 6B. At time t1 (Fig 6A), two separate concepts are shown, sets A and B, with three interrelated areas of endeavor, 1, 2, and 3. At a second time, t2, A has expanded to embrace B, and 1 and 2 have fused into a single theoretical construct. In addition, a completely new area of theory, set 4, has started.

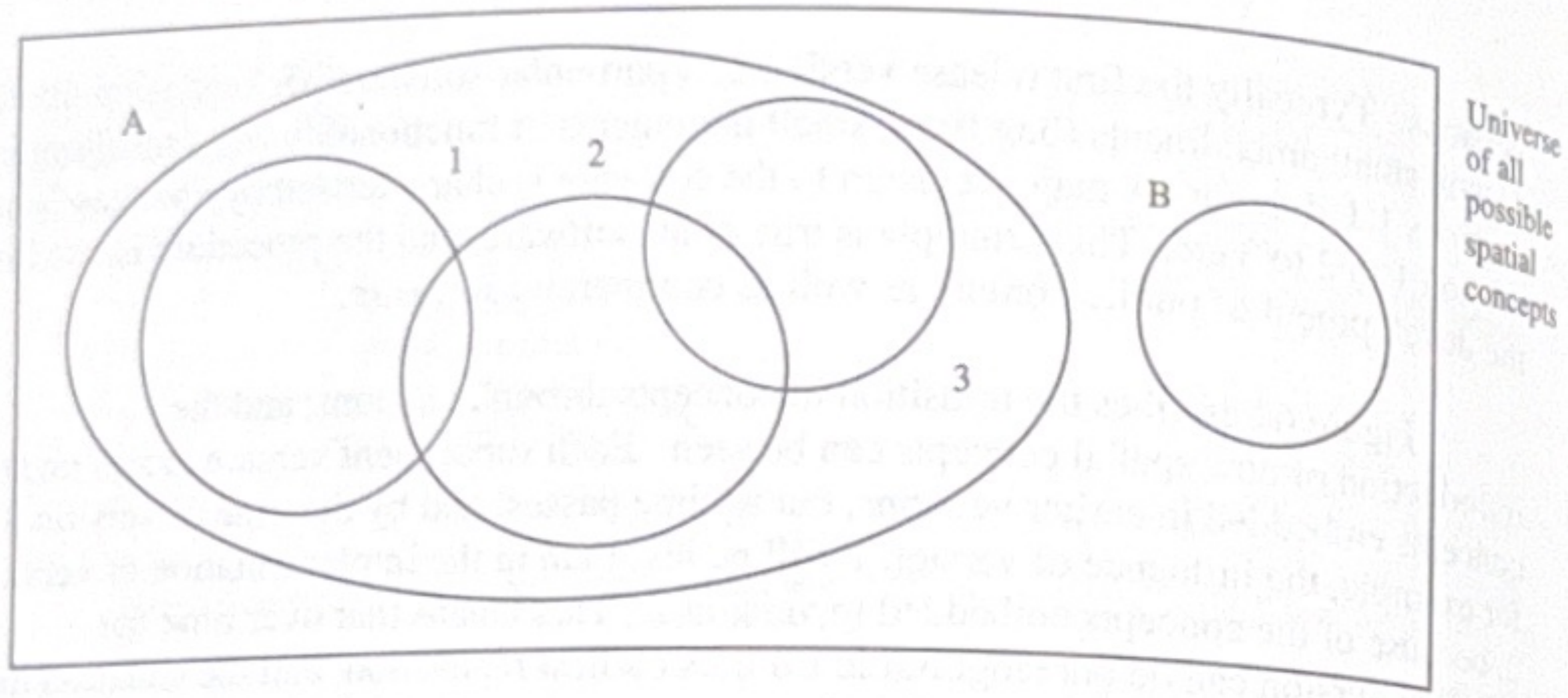

Figure 6A. The state of GI Science at time, t1.

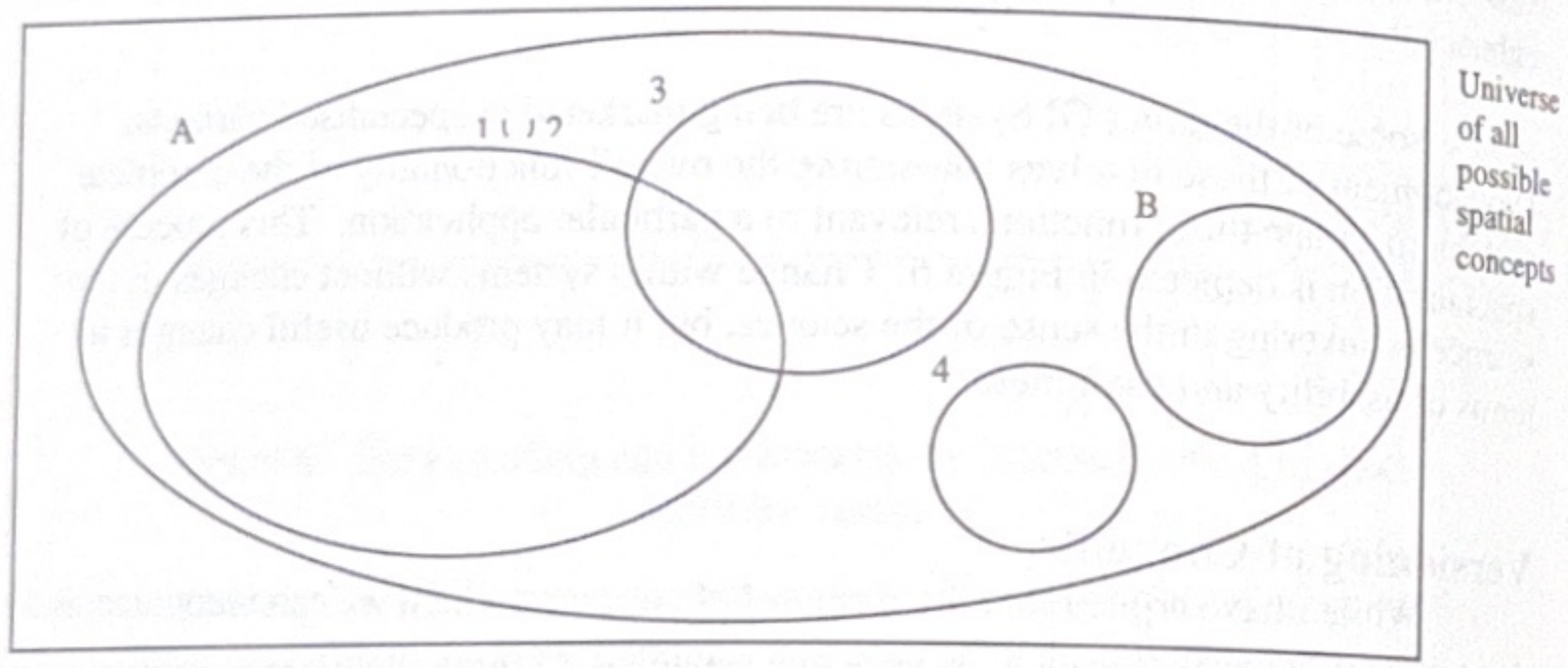

Figure 6B. The state of GI Science at time, t2.

Conclusion

GI Systems are not perfect tools for many applications because they represent an implementation of a state of GI Science. For an application in hand, a particular system may be good enough, but it may not. It is essential that the GI Scientist (as opposed to technicians, although it is to be hoped that they are one and the same person) can evaluate the utility and applicability of the spatial concepts embodied in the system in use for the application. The difference between a technical training in GI Systems and a scientific training in GI Science is the knowledge to critically evaluate the science embodied in the system and to be able to develop new theory to work around the problems. Therefore, the Bi-Cyclic model supports the concepts of education in GI not being grounded in button-pushing skills (Unwin et al, 1990; Kemp and Goodchild, 1992). A true education in GI Systems and an education in scientific use of GI Systems even as a tool in an application discipline requires an understanding of the spatial concepts implemented within the GI System in use, and an awareness of the system options and possible alternatives.

Furthermore, it can be argued that the critical use of GI Systems provides an incomparable testing ground for the concepts of GI Science, and that a very real symbiosis exists between the two. Uncritical use of GI Systems, however, can only be described as *bad science*, in either the sense of geographical science or application science. That is not to say that such use of a black box does not fulfil a role in policy formulation and planning which may even be useful, but such use does not of itself constitute science in any strict definition, although it may be part of technoscience (Latour, 1982).

There are many examples that can be drawn on to illustrate the advance of geographical science, the versioning of software, and their interplay. Space here precludes development of these examples, but I do not believe that many people working within the GI arena will have problems identifying the ideas illustrated. Further work will develop hard examples of the concepts presented

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Specifications For Interoperability: Formalizing Image Schemata For Geographic Space

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Abstract

The formal specification of spatial objects and spatial relations is at the core of geographic data exchange and interoperability for GIS. Spatial image schemata have been suggested as highly abstract, structured schemata to capture spatial and similar physical as well as metaphorical relations between objects in the experiential world. We assume that image schemata for geographic (large-scale) space are potentially different from image schemata for table-top space. Formal definitions of four image schemata (LOCATION, PATH, REGION, and BOUNDARY) are given.

Keywords

Naive Geography, Image Schemata, Location, Region, Qualitative Spatial Relations.

1 Introduction

Exchange of data between GIS and interoperability of different vendors' GIS software are topics of enormous practical interest (for example, documented by Buehler and McKee (1996) and the recent Interop97 conference (Goodchild *et al.* 1998)). Unambiguous definitions are at the core of any effort to achieve the necessary standardization that allows data exchange and co-operation of different GIS.

Standardization of technical terms and the fundamental concepts necessary to make computers interact is mostly achieved or can be achieved with current tools. The abstract behavior of computerized systems can be specified in a formal language and it then requires the checking of the compliance of the target computer system— which is by definition also a formal system— with the abstract formal system. This problem is not particular for GIS but general for all computer system standardization. The difficulties are of a practical nature and related to the lack of formal definition of most current computer languages, commercial interests in maintaining incompatible systems, and the rapid development compounded with legacy systems.

The economically important and scientifically challenging question is to describe the meaning of GIS data in terms of the real world, the so-called "semantics problem." What does it mean that "P 271" is a point, "343a" a land parcel, that building "A1" is on parcel "343a," A-town is on the B-river etc., and how is this meaning communicated between systems. The naive assumption that a "rose is a rose is a rose" (Gertrude Stein) is obviously not correct: the definitions of simple geographic properties differ from country to country, despite corresponding names (Chevallier 1981; Mark 1993; Kuhn 1994).