The Current Status of GI Approaches in Human Geography: A Review of Mainstream Journals

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The current status of GI approaches in human geography was surveyed in 19 mainstream geography journals. The survey reveals a notably low number of research articles referring to this field in these journals. The deficiency is emphasized in a comparison with the situation in journals of hydrology, soil and ecology and is quite remarkable considering the vast number of GI methodologies available in GI journals. On the other hand, a limited (6-year) multi-temporal analysis of the survey's results is more encouraging: in some of the mainstream geography journals the appearance of studies that include GI approaches in human geography increases gradually. This paper analyzes the actual status of GI approaches in human geography against its potential and provides explanations for the current disparity between them.

Keywords: GIScience, GISystems, human geography, geography journals.

The new field of Geographical Information Science (GIScience) provides paradigms and methodologies that allow users of Geographical Information Systems (GISystems) to store, analyze and display geographic information (GI). As such, approaches of the two fields are prime candidates for use in various geographical fields—among them human geography. The rapid development of computer technology during the 1990s, which has made vast amounts of GI available to human geographers, has made GI approaches even more attractive and could encourage new avenues of research.

GI approaches in human geography have been discussed from various viewpoints in several studies. A few representative examples are described as follows. Poulsen (1994) points to the dilemmas in the association between positivist and postmodernist human geography and the GISystems approach. Openshaw (1998) presents a comparative discussion of the strengths and weaknesses of GISystem methods in human geographic research. He suggests a broad approach and asserts that the use of the recently emerging geocomputational[1] paradigm can act as a bridge to the quantitative methodologies in human geography. Martin (1996, 1999) describes aspects of representing socio-economic phenomena within GISystems (mainly with regard to

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census data). In these studies, Martin reveals the advantages and disadvantages of GISystem tools for the manipulation and modeling of socio-economic data.

The use of GISystems for social issues has also been studied from a regional aspect. In an editorial paper to the international journal *Computers, Environment and Urban Systems*, Craglia (2000) discusses the association between GISystems and the social sciences from a European point of view. This study focuses on the data needs for social science applications in Europe and reviews the results of the GISDATA program of the European Science Foundation. Other studies, such as Schuurman (2000), have summarized the critics on GISystems and their social effects, while others, such as Fotheringham et al. (2000), have discussed the relationship between quantitative geography and social theory.

These studies and others provide interesting and important information about the different uses of GISystems in the social sciences, but do not discuss the status of GI approaches in human geography as presented in the scientific literature of geography journals. As such, the existing studies focus on conceptual and technical aspects and the components needed for social applications of GISystems. Consequently, a scientific review of GI approaches in human geography journals is missing.

This paper is aimed at discussing the up-to-date potential of GI approaches in human geography research. This potential is examined against the actual status, based on a survey in 19 mainstream geography journals. It is assumed that fulfillment of this paper's objective may contribute to a better understanding of the current attitude among scholars to the use of GI methodologies and paradigms to explore human geography. The section below introduces human geography and GI fields in terms of their common characteristics. It also describes in detail the potential of using GI approaches in human geography and reviews the actual situation. It is followed by a comparative discussion section and, finally, by a summary and conclusions.

THE FIELDS

Human Geography

Human geography is a broad subject. Some of its background is introduced here, but its various fields and sub-fields are well beyond the scope of this paper. The purpose of the introduction provided here is to present the fundamentals, entities and relationships of human geography that might share common ground with GI fields. Human geography is defined in the *Oxford Dictionary of Geography* as 'a generalized term for those areas of geography not dealing exclusively with the physical landscape or technical matters' (*Oxford Dictionary of Geography*, 1997:215). A more careful definition is that by Johnston in *The Dictionary of Human Geography* claiming that human geography is 'That part of the discipline concerned with the spatial differentiation and organization of human activity and its relationships with the physical environment' (Johnston, 2000:353).

During the first decades of the 20th century most human geography studies covered human-environmental interrelationships and their regional variations, leading to the establishment of the sub-disciplines such as economic geography, urban geography, social geography, cultural geography and political geography after World War II (Johnston, 2000). However, the field has since developed through changes that have led to the establishment of two new geographies during the second half of the century (Robinson, 1998). These two distinct approaches appear to be both conflicting and complementary. The first approach, known as the 'quantitative revolution', began its development during the 1950s and 1960s and is based on the adoption of statistical and mathematical methods for human geography analysis, mainly founded on logical positivism. The second approach was developed during the mid- and late 1980s, adopting methods of social sciences through ideas such as the critical social theory, and combining humanism, Marxist traditions and postmodern thinking. The rise of the latter approach was mainly due to criticism of quantitative geographers (e.g., Bennett, 1981), claiming that many uses of quantitative methods are only loosely tied to a positivist idea and that in their devoutness to quantification, some human geographers oversimplify processes. Although they are very different in their nature, the research procedure in both schools of human geography is necessarily related to spatial representation and analysis, including designated entities in complex relationships.

According to the quantitative approach, Wilson and Bennett (1985) categorize the entities that constitute the subject matter of human geography: people and organizations, goods, services, commodities, land and physical infrastructure. In a broad sense, the people and organizations are the agents that produce the overall geographical structure, while the other entities are the inputs and outputs for the activities of the first two. The different entities, under appropriate assumptions, could be specified in terms of various mathematical descriptions, where the simplest example is algebraic. In this case, attributes of individual observations could be described as variables and the relationship between the observations could be described by equations composed of coefficients and parameters. The ability to represent human geography entities and relationships with mathematical and statistical tools launched the adoption and use of advanced methodologies from exact sciences for modeling and studying human geography phenomena and processes. For example: Markov chains could predict the probability of element distribution along the time domain (Collins, 1970; Bourne, 1969); a bifurcation theory could characterize the nature of three-dimensional surfaces (Sonis, 1996; 2000); the Lowry model of the urban structure (Lowry, 1964; Wong et al., 1999); and the central place theory, which is mainly based on simple economic rules and the mathematical representation of the Voronoi diagram (Christaller, 1933).

In contrast to the quantitative approach, the qualitative approach does not bind the entities to a positivist idea and the development scenarios of human environments are based on social forces and ideas. Gregory (1994) summarizes earlier studies that illustrate human geography structures according to the social theory.

This is founded on a geometrical approach, whereby spatial analysis is utilized by the decomposition of regional systems into a series of abstract geometries: networks, movements, surfaces, nodes and hierarchies (Haggett, 1965). This approach seems to be a comprehensible method of describing space but is criticized by Haggett himself, who later claims that 'order depends not on the geometry of the object we see but on the organizational framework in which we place it' (Haggett, 1965:25). In its development, the social approach, led by Harvey (1973) and others, was exploring ways of contravening the limitations inherent in the geometrical structures and thus enabling analyses of spatial patterns in accordance with social processes. In achieving this, the entities are related to wellknown nonspatial processes that are translated by human geographers into spatial processes. Data representation in this case cannot be as rigid as algebraic formulae and therefore require tools that are more advanced to represent vague processes.

GI Fields

GISystems has been an active field of research and application since the 1960s. Numerous scholars and professionals in the GI industry have provided definitions for this field (a detailed discussion of definitions of GISystems is presented by Chrisman, 1999). Tomlin offers a typical scientific definition: 'GISystem is a facility for preparing, presenting and interpreting facts that pertain to the surface of the earth' (Tomlin, 1990:xi). According to an industrial source, 'GISystem is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information' (ESRI, 1990:1–2). These two examples are indeed functional and could imply that GISystems can be considered a subset of the IS (Information System) discipline, with a unique specialty in the spatial domain. As stated by Star and Estes, 'GISystem is an information system that is designed to work with data referenced by spatial or geographic coordinates' (Star and Estes 1990:1). As an IS, a typical GISystem includes: an input source that could be remote sensing imagery or digitized data; a geographic database; output capabilities, such as plotter or on-screen tools; and analysis/querying algorithms. Akin to other unique ISs (such as medical IS) GISystems are supported by an explicit scientific basis that provides a theoretical backup for their functions and capabilities. Computational paradigms from IS engineering is included in the scientific basis for GISystems, alongside a strong geographical foundation that is comprised of: representation of spatial entities and their behavior in space, theories of spatial analysis, and principles of generalization and symbolization.

The synergy between the two disciplines (IS and Geography) has encouraged the appearance of a new field to satisfy the special needs of GISystems. GIScience refers to the set of basic concepts on which GISystems are built (Fisher, 2001; Frank, 2000). GIScience is devoted to fundamental research issues, such as the definition of spatial data models; geo-referencing of geographic databases; and spatial querying systems.

GIScience should be clearly distinguished from the GISystems software research and development: the latter is usually funded by the industry and its research arena is consequently affected at times by commercial considerations.

Although the debate over similarities and differences between the science and the system has not been fully satisfied (Wright et al., 1997), the abstraction stated by Fisher and other authors is that GISystems are implementations of concepts provided by GIScience. Fisher (2001) claims that GISystems play a key role in the development process of ideas and tools provided by the science, and use the widespread implementation of these ideas and their exposure to critiques. This implementation and exposure are basic elements of any scientific process. GIScience by nature plays a fundamental role in the existence of the systems by providing the concepts for implementation. In other words, a mutual development of the two fields facilitates the use of GI.

The coexistence of GIScience and GISystems has enabled significant improvements in the representation and analysis of spatial data. A keynote publication by Goodchild (1997) describes the advantages inherent in the GISystems in comparison with traditional mapmaking. Goodchild illustrates how GISystems can handle larger datasets, which are more accessible, and can be either fuzzy or crisp to allow better communication between the information supplier and consumer. These advantages have opened new paths for the delivery of GI, which is consequently fuller, more accurate and subtle.

The improvement in spatial data analysis due to the alliance of the GI fields has also received recognition. A special issue of the *Journal of Geographical Systems* (Volume 2(1) 2000) was dedicated to the role of GI fields as a platform for spatial analysis. The provision of a wide range of statistical tools in conjunction with graphical facilities, which support exploratory analysis and regionalization devices, facilitates interaction between user and data (Haining et al., 2000; Wall and Devine, 2000). It facilitates repetitive and easy-to-use spatial analysis techniques, which can be monitored on-screen. In a broader sense, an object-oriented approach is incorporated with spatial analysis techniques (Marble, 2000). In the near future, this could enable significant improvement in the use of spatial analysis methodologies through better representation of real-world conditions with computerized tools.

Potential of GI Approaches in Human Geography

The use of GI approaches in human geography is based on an intrinsic element of the scientific essence of the two fields: the spatial aspect. Since the spatial aspect distinguishes human geography from social sciences and GI fields from IS disciplines, it would be expected that the use of GI approaches would be more common in the classic fields of human geography (such as political geography) than in other subject areas such as criminology and epidemiology.

The potential of using GI approaches in human geography can be summarized under two main topics: data representation and accessibility; and (spatial) analytic

performance. These topics cover a wide range of related yet distinct issues. Data representation and accessibility refers to matters of spatial database management and spatial data structures, while analytic performance concerns the analytic, computer-intensive methodologies earlier mentioned as the geocomputational paradigm.

As stated above, the systems involved in the sub-fields of human geography are particularly complex and the spatial representation of entities by computational means is challenging, at times even more so than in other studies of natural sciences. GI fields could facilitate computational representation by means of improved acquisition, storage, accessibility and display of geographical data. Digitized analog maps, field surveys with DGPS (Differential Global Positioning Systems) and interpretations of satellite/airborne data could be a resource for the *acquisition* of geographic data. Due to the potential of remote sensing to provide new geographic information (Curran et al., 1998:33) in a cost effective manner, it is becoming one of the prime sources for updating geographic databases.

The storage of spatial data has always been one of the strongest capabilities of GISystems. Development of designated raster and vector topological data models (Winter and Frank, 2000) and the adoption of the object-oriented approach for GI computation allow highly efficient storage of GI. This is done by means of the classes–sub-classes inheritance concept (Nunes, 1991). Use of the object-oriented approach makes GISystems designs possible with multifaceted databases, such as the temporal dynamics of the movements of groups and individuals on an urban street network (Frihida et al., 2001). Other advanced GIScience concepts enable storage and representation of imperfect spatial data, using ontological[2] engineering (Duckham et al., 2001). An ontology-based GISystem presented by Fonseca et al. (2000) shows how urban ontologies can be used to generate software components that enable large-scale data sharing and knowledge reprocessing in a detail-rich urban environment.

In addition, the very recent confluence of the fuzzy set theory and the object-oriented approach allows the development of the fuzzy data model, which is still a prototype at present (Cross and Firat, 2000) but is very promising in representation of inexact or vague spatial entities. These are just a few examples of storage capabilities to demonstrate the potential for representation of particularly complex structures in human geography.

Data *accessibility* in GISystems and geographical querying engines has progressed substantially in recent years with the development of the agent-based[3] approach. This approach provides a user-friendly description of the desired information, approximated answers if exact answers are unavailable and an efficient troubleshooting mechanism (Tang et al., 2001). The agent-based systems' navigation tools also enhance the nonspecialist's use of GI.

In the past, the display of spatial data in GISystems held key advantages over traditional cartographical capabilities in terms of symbolization (Goodchild, 1997). Today, however, the rapid development of computer graphics, visualization and animation techniques along with integration of visualization tool kits with GISystems (Dollner and Hinrichs, 2000), have advanced the ability to merge 3D images and movies within the spatial database of GISystems.

GI fields also have much to offer as platforms for spatial data analysis in human geography. The importance of spatial analysis tools integrated in GISystems and of digital data availability for better understanding of human spatial behavior has been demonstrated in the past. Kwan (2000) focuses on the advancement of GISystems capabilities to better represent and handle complex spatial data. This progress consequently enables analyses that include individual scales in the environment rather than zone-based (parcel) data which had been commonly used for studies of spatial analysis of human behavior prior to the development of GIScience paradigms. The potential hosted by GISystems has encouraged the development of several geographical analysis tools, which are now available in GIScience literature (most of them, however, have not yet been programmed into GISystems software).

The following are four examples of new geographical analysis tools (out of many others that exist in the literature and listed in Fotheringham et al., 2000):

(i) The *cluster finding technique—GAM (Geographical Analysis Machine)* is a methodology developed to identify patterns in geographical data without the use of a priori knowledge. This is done by statistical examination of the magnitude of spatial phenomena in a large number of overlapping circles of varying sizes. Once the statistical test ends and several options (with different sizes of circles) have been examined, 'interesting' patterns are presented (Openshaw et al., 1987). GAM can be used, for example, for the identification of transmitted diseases (Besag and Newell, 1991). GAM is purely automated, involves minimal end-user GI skills, is fast, cheap, efficient and relatively easy to apply (Openshaw, 1998)—all of which are important and attractive characteristics for human geographers.

(ii) The dynamical modeling of *CA (Cellular Automata)* is a methodology based on a mathematical framework that allows an iterative search for a pattern or behavior in the interaction between mesh neighboring components. CA is a well-known methodology and can be used, for example, to simulate urban and regional growth by determining how cells (as basic structures in an array) change their status based upon relatively simple, pre-defined transition rules (Batty, 1997). The transition rules can be controlled by more advanced methodologies, such as fuzzy logic (e.g., Wu, 1998). CA models have proven particularly well suited to modeling complex systems composed of a large number of individual elements linked by nonlinear coupling (Openshaw and Openshaw, 1997).

(iii) The *Neural Network (NN)* paradigm is one of the most powerful AI (Artificial Intelligence) tools for solving GI questions. It is inspired by the information processing of the human brain and is usually used in GI methodologies for pattern recognition or image classification, by means of an internal learning process. Fischer (1998) discusses the use of neural networks for solving fundamental spatial analysis problems through computational definition and mathematical terms. Neural networks can be applied to solve geographical problems, as in modeling the flow of interregional telecommunication (Fischer and Gopal, 1994), and in land cover classification and mapping (Civco, 1993).

(iv) *Geographically Weighted Regression (GWR)* is a statistical technique that can be used to examine the spatial variability of regression results across a region. Rather than accepting one set of 'global' regression results, the technique allows the production of 'local' regression results from any point within the region, so that the analysis output is a set of spatial statistics that denote local relationships (Fotheringham et al., 1998; Brunsdon et al., 1999). The use of GWR is demonstrated in Fotheringham et al. (2000), where land use (industrial regions) is linked with limiting long-term illness in Northern England.

In summary, it can be maintained that progressive approaches to the GI fields (GISystem and GIScience) in human geography have strong potential through use of the two aspects presented above: data handling and analysis. The examples provided indicate that advanced methodologies for this purpose are available in the relevant literature and that these methodologies could indeed be used in the domain of human geography studies.

ACTUAL STATUS: A REVIEW

Nineteen geography journals were selected to represent the current status of GI approaches in human geography. Although the sample could not possibly include all the relevant geography journals (a difficult task to fulfill), it is believed that the selection sufficiently represents the mainstream journals of geography. The selected journals cover various countries of publication, dates of origin and subject matter (Short et al., 2001). Seven of the selected journals appear in the list of the top ten human geography journals in 1999—ranked by citation impact factor (Martin, 2001). The time frame surveyed spans six years, between 1995 and 2000 (inclusive). A similar survey of earlier years could not be found and it is believed that the given time frame reflects the up-to-date trends of these journals in conjunction with the recent development of GI technologies. The results of the survey are presented below as follows: (i) a report of the total number of relevant articles appearing in the journals; (ii) a reference to the appearance of relevant articles in the individual journals; and (iii) a limited multi-temporal account along the chosen time scale.

The total number of research articles (excluding book reviews, comments, etc.) published in the journals presented in Table 1 is 4,628 (excluding the years that were not surveyed due to problems of availability—see asterisk in Table 1). Of these, only 2.38 percent are articles that can be defined as studies of GI approaches in human geography.[4] For comparison, in the related field of remote sensing the situation is even worse where only 0.51 percent of the papers were involved with remote sensing approaches.

A decomposition of the results according to individual journals reveals a nonhomogenous distribution of the relevant papers (Figure 1). The journal *Geographical Analysis* gave stage to the highest number of studies including GI approaches in

Table 1: Proportions of GIScience and GISystems related papers in human geography journals 1995–2000.

Journal	*No. papers that could be related to GIScience or GISystems*							*Total no. of papers in 1995–2000*
	1995	1996	1997	1998	1999	2000	Total	
Progress in Human Geography	1	1	0	1	0	3	6	200
The Professional Geographer	0	1	0	0	3	2	6	243
Regional Studies	0	0	0	0	1	0	1	650
Journal of Historical Geography	0	0	0	0	0	0	0	118
Political Geography	0	0	1	0	0	1	2	286
Economic Geography	0	0	0	0	1	0	1	228
Geographical Review	2	9	0	0	0	0	11	476
Transaction of IBG	0	1	0	0	0	0	1	175
Urban Geography	0	0	2	2	1	2	7	262
Geography	0	0	0	1	1	1	3	242
Environment and Planning A	1	0	2	10	3	5	21	664
Area	1	0	1	0	0	0	2	152
Geographical Analysis	4	5	2	0	4	3	18	120
Annals of AAG	3	1	4	1	1	3	13	130
Geografiska Annaler B	1	2	0	1	0	0	4	70
Tijdschrift	2	2	3	1	3	1	12	172
Geoforum	1	0	0	0	0	0	1	187
Society and Space	0	0	0	1	0	0	1	242
Journal of Cultural Geography	0	0	0	*	*	*	0	11
Total annual	**16**	**22**	**15**	**18**	**18**	**21**		

* year not surveyed

human geography. More than 10 percent of its articles published between 1995 and 2000 report on these studies, most of which are strongly related to GIScience, methods and theory. Other journals published noticeably fewer studies of that kind. These are: *Annals of the AAG* (10 percent); *Tijdschrift voor Economische en Sociale Geografie* (6.9 percent); and *Geografiska Annaler* (5 percent). The next group of journals provided between 2 percent and 3 percent related articles (listed in order from higher to lower percentages). These are: *Progress in Human Geography, Environment and Planning A, Urban Geography, The Professional Geographer, and Geographical Review*. The third group of journals, which published 1–2 percent related articles,

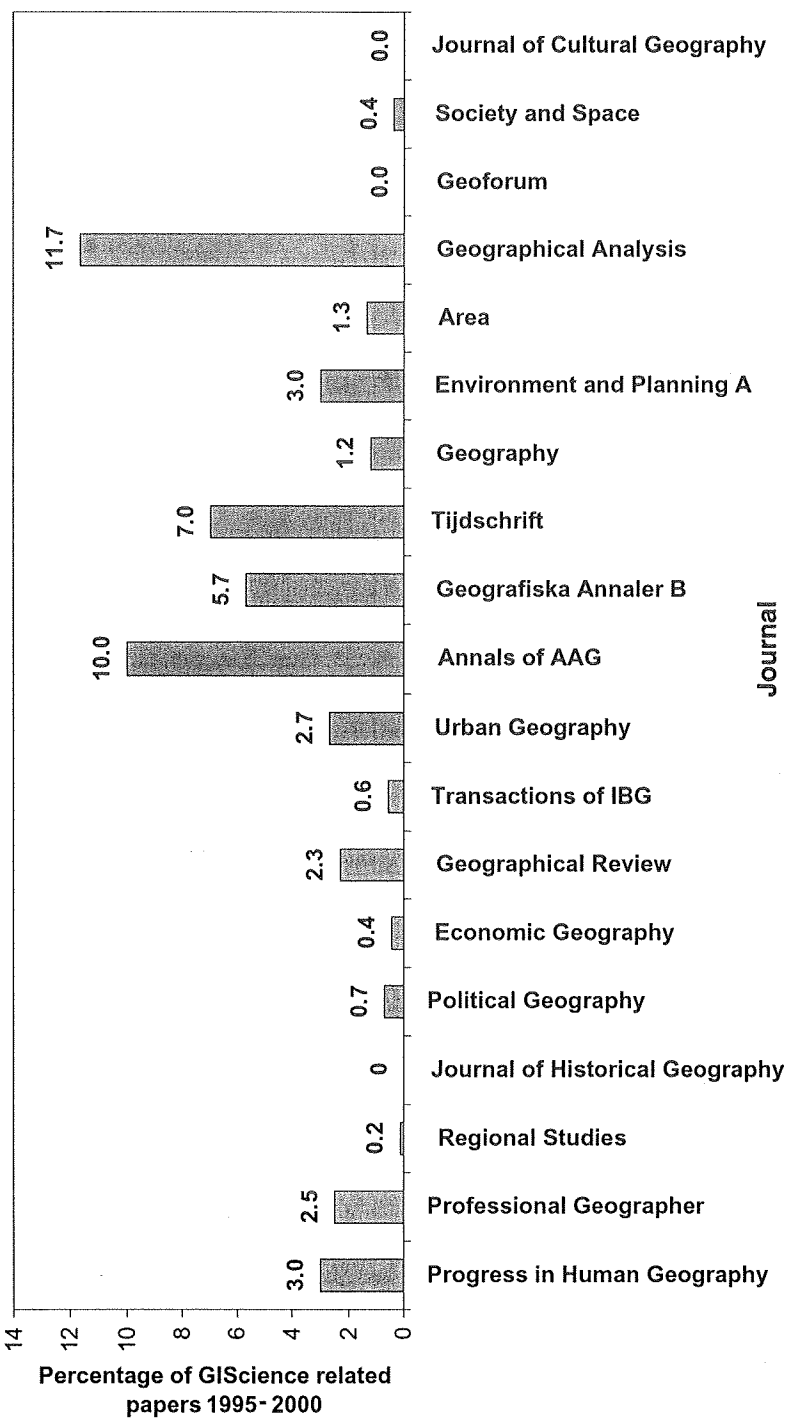

Figure 1: Papers of GI approaches in human geography in the mainstream journals surveyed. Percentages were calculated from the total numbers of all research articles published in each journal between 1995 to 2000.

includes two journals: *Area* and *Geography*. The fourth group, in which less than one percent of the papers relate to GI studies, includes: *Political Geography*, *Transactions of IBG*, *Economic Geography, Society and Space* and *Geoforum*. *Journal of Cultural Geography* and *Journal of Historical Geography* did not include a single paper that could be related to GI fields during the years surveyed (note the exception of the years that were not surveyed in *Journal of Cultural Geography*). As such, almost half of the journals allocated less than one percent of their publications to themes of GI approaches in human geography.

The total number of relevant papers published per year generally increased over the years (excluding 1996, when *Geographical Review* issued a one-time special issue that multiplied the annual number significantly). Table 1 shows the total number of relevant studies shifting from 16 in 1995 to 22, 15, 18, 18, 21, and finally 17 in the year 2000. However, when surveying the individual journals, this trend cannot be observed. The changes are minimal in the individual journals and it is the sum of these very slight differences that makes up the slow but observable tendency as a whole. The multi-annual observation also reveals phenomena such as in the *Geographical Review,* which published 11 relevant papers in 1995–1996 but none in the following four years. *Environment and Planning A* (*EPA*) also created an unstable result due to the '10+11 theme issue', published in 1998. As opposed to *EPA*, *Urban Geography* is more stable but provided fewer papers.

DISCUSSION

The potential of GI approaches in human geography has been described in detail in the present paper and is shown to be particularly promising in terms of both spatial data management and analysis. The rapid development in computer sciences (hardware and software) and in spatial analysis is likely to increase this potential dramatically within the next few years. Typical GI journals, such as *Computers, Environment and Urban Systems*; *Geoinformatica*; *International Journal of Geographic Information Science*; *Journal of Geographical Systems*; *Transactions in GIS* and others, have acknowledged this potential and consequently offer many GI methodologies that have been developed for different fields of human geography. The availability of methods in GI journals and the relatively small number of related papers in mainstream geography journals may imply that research involving human geography and GIScience is more widespread than implementations of GISystems in classic human geography research. This statement is supported by the literature survey provided here. *Geographical Analysis*, an international journal of theoretical geography that focuses on methodologies rather than applications, has published relatively more related papers than the 'applied journals'. Other journals, in the second group of 2–3 percent (see above), published papers that are mainly focused on methodology development rather than applications (see for example *EPA*'s theme issue). An exception is the special issue of *Geographical Review*, which provides a

review of case studies for the implementation of GISystems in business, society and management. Another, rather important, exception is made by the fact that this survey refers to the mainstream geography journals and therefore excludes information about GISystems application studies published in GI journals or others. It should be noted that GI journals are relatively recent and authors publishing in these journals could have been submitting similar publications to mainstream geography journals in the past. However, it can be concluded that the availability of GIScience methodologies for human geography subjects did not lead to massive publication of GISystems implementations in human geography case studies in the mainstream geography journals. For example, GI approaches in cultural, historical and political geography seem to be among the matters most disregarded by international journals. Typical journals of cultural and historical geographies too, did not present any relevant studies perhaps due to their closeness to the humanistic element of human geography. In the case of political geography, despite the existence of GI techniques for the representation of border transformation, only two relevant studies could be found during the period surveyed.

GI techniques have been applied to the field of urban geography in a large number of research studies. Wu, for example, provides a comprehensive discussion of urban simulation (Wu, 2002, this issue). The correlation is reflected in the present survey, ranking the urban geography journals in the second group (2–3 percent). The relatively wide application of GI techniques to urban geography could be explained by the urban environment that encourages GIScience specialists to test their methodologies against its richly detailed infrastructure. Another basis for this could be the large expenses involved in urban planning and development. Governmental and local offices are consequently willing to contribute funds towards urban simulation in order to minimize the necessary expenses involved in the construction process. Perhaps stemming from the same grounds, relevant studies of rural space and open areas are lacking. *Regional Studies*, for example, provides only one paper on the classification of rural areas (1998) and one dealing with woodland recreation (1999), both of which are methodological in nature. Similarly, *Area* provides one paper concerning nonracial school system planning in rural areas and a discussion of the role and importance of GISystems in Third World countries. *Geography* and *Society and Space* has given even less coverage to the topic and publishing only papers on thoughts and ideas regarding the role of GISystems. This gap exists despite the fact that spatial analysis techniques for studying rural space have been developed for various purposes, such as accessibility to services in rural deprivation research (Higgs and White, 1997; White et al., 1997).

The lack of studies using GI approaches in human geography is further enhanced in comparison with relevant ratings in mainstream journals of physical geography. In the hydrology field, for instance, in 2000 alone the journal *Hydrological Processes* published 31 out of 195 research articles relating to GI fields (16 percent of its publications). However, it should be noted that these numbers include papers that appeared in a special issue. In *Geoderma*, nine related papers were counted,

constituting just over 10 percent of the entire research papers published by that journal in 2000. In the field of ecology, Carmel conducted a literature survey of the three major international journals: *Ecology*, *Journal of Ecology and Journal of Animal Ecology* (Y. Carmel, unpublished data). Carmel compares 1999 and 1987. In 1999, 20 out of the 154 surveyed articles presented ecological models, of which 12 were spatial models. In 1987, ecological models were the subject of 14 articles of the 145 surveyed, none of which was a spatial model. This data may imply that the effort in ecological modeling is shifting toward the spatial domain, although it is not a typical spatial/geographical field.

The question remains whether the lack of GI papers in human geography journals is due to editorial policy or to lack of submissions is beyond the scope of this paper and deserves a further study. Nevertheless, it is hoped that GI approaches in human geography will swing in a direction similar to that in the adjacent field mentioned above. The multi-temporal analysis gives evidence of a small, but important, increase in GI-human geography papers published in mainstream geography journals between 1995 and 2000. The results do not form a basis for prediction for the coming years, but if the number of relevant papers will indeed rise, given the potential of GI approaches in human geography, it would certainly benefit the scientific community.

CONCLUSIONS

GI approaches in human geography do indeed hold encouraging potential, yet the number of research articles in geography journals referring to this matter is notably low (in contrast to the status in mainstream journals of physical geography/earth sciences). This shortcoming could be based on the difficulties involved in representing the human infrastructure and behavior in space, which is, in many cases, more complex and dynamic than the infrastructure and entities in natural sciences.

Such complexity could also be the reason for the greater focus on the development of GIScience methodologies in human geography rather than the use of these methodologies in a well-organized GISystem of the human environment. On the one hand the complex environment encourages and challenges GI scientists to develop methods; on the other hand the results of GISystems that have been implemented for human geography problems have been so complicated that scientists have often found them difficult to interpret.

In view of the trends discussed in this paper, it is proposed that the use of GI methodologies to answer questions in the various fields of human geography should be seriously encouraged by authors and editors. Studies that have shown the added value of GI approaches in human geography will ultimately encourage human geographers to use available methodologies to their advantage. It is hoped that a rising trend in publishing GI related papers in mainstream geography journals, although exceedingly slow and uncertain at present, will increase and spread to the other journals. Consequently, in the coming years this field should benefit from

an increase in published research papers that involve GI methodologies in human geography studies.

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NOTES

1. The term geocomputation was coined by Openshaw and Abrahart (1996) to describe the use of computer-intensive methods for geographic knowledge discovery, especially using advanced dynamic modeling visualization and space-time dynamics.
2. Guarino (1998) has defined ontology as a logical theory accounting for the intended meaning of a formal vocabulary. The use of ontologies allows the establishment of correspondence and interrelations between the various domains of spatial entities and relations (Smith and Mark, 1998).
3. Agents are intelligent software tools that carry out tasks on behalf of human computer users (Muller, 1997). The use of agents is widespread in information systems engineering and has been adopted during recent years by the GI world.
4. Papers that have used or developed GI methodologies, or even discussed the two possibilities. The titles of all papers in the 19 journals from the period surveyed were examined. Studies that were totally unrelated were excluded. Later, the abstracts of potential papers were examined and in cases of a doubt, the manuscript itself was read.

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