

CSISS: A CENTER FOR SPATIALLY INTEGRATED SOCIAL SCIENCE

INTRODUCTION

The analysis of space and place has become an increasingly pivotal component of social science research during the past two decades. In part this is attributable to the transformation of social space around the globe, accompanied by shifts of varying degrees of magnitude in social science conceptualizing and theorizing. One aspect of these changes is subsumed under the general notion of “space-time compression” and results largely from such revolutions in information and communication technology as the microchip, satellite television, and low-cost, high-volume transoceanic shipping and travel. Other rapid transformations result from huge shifts in populations across the globe in migrations of unparalleled scope and scale. Also of note are the changing political landscapes of the late 20th Century with their kaleidoscope effects of expanded (e.g., the European Community) or contracted (e.g., former Soviet Union states) territorial boundaries. All of these changes in the space and place of peoples and nations have profoundly affected the spatial organization of the social, the economic, the political, and the cultural—the key domains of focus of the social sciences. Thus, the social sciences manifest enormous interest in space and place, and their changes through time. Yet, while a growing number of social scientists have taken up the use of the sophisticated technology and new methodologies of spatial analysis (such as geographic information systems, GPS, remote sensing, and spatial statistics), we believe that recent advances in both theory and methodology can be extended substantially to enable many more social scientists to address these key issues, by means of fine-grained spatial analyses that are not possible with conventional tools. Further, and as elaborated below under our Vision, we believe that a concerted effort to enhance the ability of social and behavioral scientists to adopt a spatial approach, through the six infrastructure programs outlined in this proposal, would return immense long-term benefits in the form of scientific progress.

In this proposal we build on the repositories of knowledge and skills of the National Center for Geographic Information and Analysis and the Varenus Project and propose a systematic program for extending the analytic power of sophisticated spatial analysis to the social sciences. More specifically, there are several reasons for believing that a stronger emphasis on space might be beneficial to the development of the social sciences at this time:

1. The past two decades have seen enormous advances in the power of information technologies. The development of the geographic information technologies, notably geographic information systems (GIS), has made collection, handling, and analysis of spatial data far easier than before. It is now comparatively easy to sift through large amounts of social data looking for patterns and anomalies, leading to the development of new and interesting hypotheses. The term *exploratory spatial data analysis* (Anselin 1999) encompasses a range of novel ideas for inductive examination of data from a spatial perspective.
2. Analysis of spatial data has been severely hampered in the past by the annoying tendency for such data to violate the standard assumptions of statistics, notably independence and stationarity. Recently, methods for handling these problems have advanced dramatically, through the development of spatial regression, spatially weighted regression, and related methods of spatial statistics, and these methods are now suitable for widespread dissemination and use by social scientists.
3. There is a resurgence of interest in the explicit inclusion of space in the theory of several disciplines. Rather than assume a single, homogeneous population of agents with uniformly perfect information, there is increasing interest in models of spatially dispersed and heterogeneous populations with imperfect communication.
4. More and more scientific attention is being directed to systems consisting of large numbers of interacting agents with complex behaviors. The goals of this work are not always the traditional ones

of discovery of simple, general principles, since it is considered unlikely that such principles will emerge given the degree of complexity in the system. Rather, such systems provide norms for comparison with real behavior; and differences between model and reality provide the basis for improvement in our understanding of the general principles programmed into the models.

5. Although basic science is directed at the discovery of general principles, the ultimate value of such knowledge, apart from simple curiosity, lies in our ability to apply it to local conditions, and thus to determine specific outcomes. Although such science may itself be place-less, the application of scientific knowledge in policy inevitably requires explicit attention to spatial variation, particularly when the basis of policy is local.
6. Space provides the framework for the integration of different social processes, and hence different domains of social science. Reductionist traditions in science have led to our current arrangements, in which different classes of processes are studied largely in isolation, in distinct disciplines, and often without specific attention to space and time. But in the real world these separate processes interact, in spatio-temporal context. New tools and data sources now allow treatment of this more general case.

We argue therefore that a spatial approach provides a compelling basis for integration among the sciences and elaborate on its specific role within the social sciences in what follows.

The Importance of Space and Place in the Social Sciences

The study of space cuts across a broad range of social science disciplines, raising fundamental questions about the location of human activities, the construction of social space, and the relationship between social space and physical environment. Below, we list some illustrative examples of areas of study where *thinking spatially* and the application of spatial analysis has changed the way social scientists approach scientific problems, and has created a demand for increasingly sophisticated methodological tools and conceptual frameworks that explicitly incorporate the role of space. What follows is inevitably only a sampling of a vast literature that spans the social and behavioral sciences and their interfaces with many other disciplines.

Several of these areas have been explored as activities of the National Center for Geographic Information and Analysis and its current Varenus project, and our current proposal is informed in many ways by the outcomes of these past activities, especially by the research agendas developed by Varenus workshops (for additional detail see Results of Prior Support and www.ncgia.ucsb.edu).

Environmental and climate change. Remote sensing, GIS, and spatial econometrics have already been used effectively to analyze the relationship between human activities and local environmental change, in particular in the area of deforestation and changing patterns of land use (Chomitz and Gray 1995, Moran and Brondizio 1998, Nelson and Hellerstein 1997, Wood and Skole 1998). Indeed, the entire issue of environmental sustainability has a crucial spatial dimension that researchers across the social sciences are addressing substantively, methodologically, and theoretically (e.g., Bockstael 1996, Bray 1998, Escobar 1995, Stonich 1998b). On the most material level, archaeologists have been at the forefront of social scientists incorporating sophisticated methods of spatial analysis—for example, using sophisticated spatial analysis to model and compare prehistoric and contemporary archeological and social phenomena in the Petén, Guatemala (Sever 1998). However, beyond the material aspects of human life, the analysis has been far more limited. The relationship between human activities and global climate change remains only partially articulated. Earth system scientists have developed powerful models that explain and predict such change on a purely physical basis—for example, the National Center for Atmospheric Research (NCAR)'s Climate System Model, which models complex interactions of all aspects of the climate system—atmosphere, ocean, cryosphere, hydrosphere, biosphere, terrestrial ecosystems, and land surface processes. Such models have yet to account adequately for regional climate change variations that are due to human effects, such as regional differences in population growth, migration, industrialization, and urbanization. Some human impacts are relatively localized; others may aggregate into more global

changes. The reciprocal relationship between socioeconomic and physical change requires the integration of socioeconomic data into existing physical climate change models, with special attention to spatial as well as aggregation effects. Social scientists have begun to work with Earth system scientists to address these issues (Berk 1992a,b, Kolstad 1998); spatial analysis will play a central role in their efforts.

Urban studies. Urban sociologists, geographers, and economists theorize that the economic role of cities is changing in light of their increased ease of access to distant economic activities. For example, cities and regions are now seen increasingly in terms of their role in global financial transactions (Sassen 1993, 1994, 1996), industrial production chains (Gereffi 1994, 1997, Appelbaum *et al.* 1993), evolving trading structures (Ioannides 1997), and interacting networks (Glaeser *et al.* 1992, Krugman 1991) leading to new conceptualizations about hierarchies of place that are tied to global as well as regional geographies. At the same time, there is renewed interest in the importance of purely social interactions that contribute to strong regional economies and unique institutions and cultures (Akerlof 1997, Arnold and Appelbaum 1995, Borjas 1995, Glaeser *et al.* 1996, Logan and Molotch 1987, Soja 1997, Scott and Soja 1998, Storper and Walker 1989). Such interactions are often seen as purely economic in nature—the role of face-to-face interactions in reducing business transaction costs. But the symbolic meaning of location can also have economic effects, as is evidenced by the concentration in Los Angeles of industries that benefit from the cultural significance of that location (Molotch 1995). GIS analyses have already been used to examine the relationship between ethnicity, space, and the location of production in Los Angeles' apparel industry (Bonacich and Appelbaum, forthcoming). In addition, the empirical validation of many of the new theoretical constructs related to interacting agents require the explicit account of space, location, and spatial interaction that can be provided by the methodology of spatial statistics and spatial econometrics.

Social and economic inequality. The spatial distribution of inequality has long been of interest to anthropologists, sociologists, and political scientists (e.g., Harvey 1996). The existence of regional and intra-urban concentrations of poverty, frequently alongside wealth-generating activities, lends itself to spatial analysis. For example, it has been argued that cities such as New York, London, and Tokyo serve not only as global financial centers and corporate headquarters, but for that very reason also create spatial concentrations of minority (and often largely immigrant) populations who provide the necessary supportive services (Sassen 1993, 1994). To take another example, one of the most controversial recent issues in U.S. race and ethnic studies is whether multi-generational poverty among blacks and Hispanics can be partly explained by their spatial concentration in urban *hyper-ghettos*, from which both job opportunities and middle-class role models have fled (Wilson 1987, 1997). The study of spatial distributions of wealth and poverty, including their persistence over time, could benefit from recent advances in spatial analysis (Anselin 1988).

Social and business networks. Social networks in general are fundamentally conceptualized in terms of spatial disaggregation, and many social scientists are analyzing the spatial aspects of networks—for example, in tracking transnational migration (Kearney 1995) or identifying high-risk populations (Brown *et al.* 1998). Paralleling the work on social networks is the recent attention in economics to interacting agents and related notions of strategic interaction. This demands an explicit account for spatial interaction and spatial dependence in empirical models, requiring sophisticated spatial econometric methods, many of which have yet to be developed (e.g., Besley and Case 1995, Brueckner 1998, Case *et al.* 1993, Murdoch *et al.* 1997). Business networks are also a focus of extensive spatial analysis. In many industrial firms, particularly those that depend on large retailers to market their products, an increasingly broad range of economic activities that were once performed by a single firm are now outsourced to independent contractors. Manufacturers of diverse products, ranging from apparel to consumer electronics, frequently depend on independent suppliers for components and even final assembly. The resulting business networks can become organizationally complex, with significant national differences in preferred modes of coordination. Japanese, Korean, or German firms tend to emphasize large-scale vertical networks; at the other extreme, Chinese or Italian firms prefer small-scale horizontal networks (Gerlach 1992, Hamilton and Feenstra 1997, Hamilton and Kao 1990, Orrú *et al.* 1997, Whitely 1992,

1996). There are a number of databases that track nationally-based trade (import-export) statistics over time, and a few that look at internal transactions among business groups for specific countries. Very little is presently understood about the mediating role of space in these arrangements, apart from fairly crude estimates concerning the costs of conducting transactions over distance (Appelbaum and Christerson 1997, Christerson and Appelbaum 1995). A spatial perspective would permit considerable refinement of these estimates.

Health and disease. Research using remote sensing and GIS has examined the cross-regional flows of disease microbes, and their relationship to changing patterns of environmental disturbance as well as more general global climate change (Epstein 1998). Public health in the United States is necessarily concerned with spatial aspects of environmental pollution, the spread and control of infectious diseases, and the delivery of critical health care and social services. The Centers for Disease Control, for example, are a leading user of spatial analysis in epidemiological studies, to help in the formulation of policy and the distribution of services, and this approach is now being replicated on many levels within the public health service (Gatrell and Loytonen 1998, Walsh *et al.* 1997). Sociologists, economists, anthropologists, and others in the environmental justice movement have extended these analyses outside the realm of public health services, to examine the spatial relationship between toxic waste facilities and other environmental contaminants and the distribution of low-income or minority populations (Bullard 1994, Collin and Harris 1993, Lee 1993, Szasz 1994). Spatial inequalities in access to health care have also been researched (Harthorn 1998, Reagan 1998). This interest adds to the growing number of demographic studies in which an explicit role is given to location and spatial interaction, e.g., in studies of contraceptive choice (Entwisle *et al.* 1997) and fertility (Tolnay 1995).

Cultural analysis and the symbolic meaning of space. Anthropologists, sociologists, political scientists, and legal scholars examine the ways in which symbolic space serves to structure and culture social activities. For example, the study of religious and ethnic nationalism, which is on the rise throughout the world today (Beyer 1994, Juergensmeyer 1993, 1995), places special emphasis on the importance of symbolic space and *imagined communities* (Anderson 1983). Special meanings are attributed to physical locations, ranging from sites with special religious or historical meaning, to entire national or transnational territories (Darian-Smith 1999, Friedland and Hecht 1996, Hancock 1999). Often this can result in the emergence of politics constructed around and through place-based identities (Keith and Pile 1993). Although the symbolic meaning of space is frequently theorized in this research, it is seldom subjected to forms of spatial analysis that might suggest uniformities across different times and places or more detailed specificities in patterns and arrays. In October 1998 one of NCGIA's Varenus workshops focused on Place and Identity in an Age of Technologically Regulated Movement, and identified a rich research agenda in this area (see www.ncgia.ucsb.edu).

Criminal justice. The causes of criminal activities are much debated by criminologists, sociologists, and economists (e.g., DeFronzo and Hannon 1998, Kposowa and Breault 1993, Land *et al.* 1990). Crimes such as theft and burglary, as well as most categories of violent crimes, are more likely to be found in low-income urban areas which have relatively high proportions of unemployed persons and racial minorities (U.S. Bureau of Justice Statistics 1997). In addition, law enforcement efforts (Chambliss 1994), gang activity (Cohen *et al.* 1998) and perception of crime (Francis and Smith 1996) also vary spatially, suggesting the need for an explicit spatial perspective (Roncek 1993). Currently, the FBI's *Uniform Crime Reports*, as well as the Bureau of Justice Statistics' semiannual *National Crime Victimization Surveys*, report large-scale spatial differences for different categories of crime (for example, urban, suburban, rural), findings which have prompted a search for spatial mechanisms such as proximity and diffusion to explain these phenomena (Messner *et al.* 1998, Morenoff and Sampson 1997, Tolnay *et al.* 1996). Crime and enforcement data are readily geo-coded, permitting social scientists to engage in much more fine-grained studies of patterns and underlying causes, and driving the demand for ever more sophisticated methods of spatial analysis.

Community studies and grassroots organizations. It is one of the paradoxes of the late 20th Century that

at the same time global forces create more interconnections among peoples, the interest in the local has exploded. As a reflection of this interest, many social scientists are engaged in community-based research with a significant if not overriding spatial concern. For example, GIS-trained anthropologists have examined the transnational interconnections (e.g., over the Internet) of grassroots and community organizations in Latin America, South and Southeast Asia, and Africa, in forming resistance to the global shrimp mariculture industry (Stonich 1998a). Sociologists at the University of Chicago use GIS and spatial analysis in studies that attempt to capture the spatial structure of the notion of social capital (Sampson *et al.* 1998). In women's studies, social scientists have become increasingly interested in closely examining the local *cartographies of struggle* for women in the developing world (Mohanty *et al.* 1991, Shiva 1989). On a more technical level, public participation GIS (PPGIS) researchers have begun to examine the social and political effects of dissemination of GIS technologies on the community level (Craig and Elwood 1998, Elwood and Leitner 1998, Harris and Weiner 1998, Talen 1999), and a Varenius workshop on PPGIS was held in October 1998 (see www.ncgia.ucsb.edu).

Vision

Our proposal is directed toward the enabling of a spatial approach to social science, and in this section we outline what this means in more detail. In general, we use the term *spatial* as shorthand for *spatio-temporal* to describe data with both spatial and temporal dimensions of variation, since most data of interest to social and behavioral scientists will be dynamic in nature.

A spatially enabled social scientist would have had opportunities for exposure to, be familiar with, or have access to:

- Concepts of representation of spatial phenomena. These would include the methods commonly associated with geographic information systems (GIS), such as raster and vector representations, issues of scale and accuracy, concepts of location, and concepts of spatial relationships.
- Tools for spatial data analysis. Such tools permit exploration of data from a spatial perspective, looking for spatial patterns, correlations, outliers, and residuals, and submitting apparent pattern to rigorous statistical tests. They also permit the confirmatory testing of hypotheses using spatial data.
- Tools for visualization and communication of spatial information, including tools for cartography and dynamic visualization. Such tools make it possible for complex, multidimensional data to be communicated visually, and for the human visual system to use its full powers of visual pattern recognition and inference.
- Tools for simulation of social systems in a spatial and temporal context, such as the spatial aspects of future urban growth, spatial behavior of individual economic agents, redistribution of global capital and industrial activity, etc.
- Principles of statistics in a spatial context, including spatial statistics and geostatistics. These include concepts of spatial dependence and spatial heterogeneity, allowing their users to deal explicitly with violations of the normal statistical assumptions.
- Methods for accessing spatial data, including search of Internet information resources based on place. Studies of spatial variation, or studies with a local focus, would be enormously facilitated by better means for searching distributed archives for information about specific geographic locations.
- Examples of advances in social and behavioral sciences that resulted from use of a spatial perspective. Much powerful cross-fertilization could occur among the sciences if there were better access to exemplary studies using spatial perspectives.

PROGRAMS

In this section we describe the six interlocking programs that will form the core of the Center's activities.

All of these programs will be informed by advances in the methods, technologies, and principles underlying spatial information technologies, notably geographic information science. SPESS will maintain strong links with other groups working in these fields, through such organizations as the University Consortium for Geographic Information Science, the National Center for Geographic Information and Analysis, and the Open GIS Consortium.

Learning Resources

A significant impediment to growth of a new approach to science is a lack of textbooks and other materials for starting courses, or for including new material in existing courses. Publishers are reluctant to encourage writing of textbooks until a market is seen to exist, and instructors are often reluctant to introduce new material without access to good resources.

At this time very few textbooks are available to support learning in spatially enabled social science, and none takes a comprehensive approach consistent with the vision outlined above. Spatial data analysis is the subject of relatively recent books by Bailey and Gatrell (1995), Cressie (1993), and Haining (1990), but only Bailey and Gatrell integrate their discussion with readily available tools and focus specifically on social science; and the tools they include have not kept up with advances in technology. Many introductory texts on GIS have appeared in recent years, but few give much emphasis to applications in the social and behavioral sciences (Martin 1996 is a notable exception). Collections on GIS applications in specific disciplines (e.g., Aldenderfer and Maschner 1996) tend to emphasize specific issues and applications, and are unsuitable as general textbooks. Books on GIS that have been written by or in collaboration with the software industry (e.g., ESRI 1997) tend to focus on applications that are commercially profitable, rather than on enabling science.

The WWW is an excellent medium for dissemination of materials in support of learning, and its use in areas relevant to spatially enabled social science has been demonstrated repeatedly (see, for example, the Virtual Geography Department project, <http://www.utexas.edu/depts/grg/virtdept/main.html>; or the NCGIA core curriculum in GIScience, <http://www.ncgia.ucsb.edu:80/education/curricula/giscc/>). Projects such as these are designed to assist instructors in assembling the materials for courses, by providing supporting notes, illustrations, examples, exam and discussion questions, and links to other resources. They leave most pedagogic issues to the instructor, focusing instead on providing content in new areas where conventional sources are not yet adequate.

We propose to develop a collection of Learning Resources in support of spatially enabled social science. The collection will be placed in the public domain, and disseminated from a central WWW server. It will be targeted to upper-division undergraduate courses, and will assume no prior knowledge of the topics addressed. It will include:

- Course notes for a series of lecture units covering all aspects of spatially enabled social science, organized as a library from which instructors can draw material.
- Descriptions of best-practice examples, drawn from across the full range of the social and behavioral sciences, and from both inductive and deductive science. These will be documented and illustrated to a level sufficient for inclusion in a course.
- Topics for class discussion, further investigation, and exams.
- References to relevant literature.
- Links to related material and other WWW sources.
- Descriptions of lab projects, to be investigated by groups using readily available tools and data.

We will not attempt to duplicate existing materials; rather, the emphasis will be on coverage of all topics relevant to spatially enabled social science, and on providing links where materials already exist.

We will organize this program as follows. In Year 1 we will appoint an Advisory Committee, chosen from educators in all of the social and behavioral science disciplines. A social scientist with a doctorate and knowledge of spatially enabled social science will be appointed to manage the project. A list of topics will be developed with input from the Advisory Committee, and construction of the WWW site will begin. We estimate at this time that a total of 120 units will be needed to cover the entire breadth of spatially enabled social science, ranging from units covering basic concepts of spatial data analysis, WWW data search, and GIS to units on spatially explicit modeling. We plan to develop these at a rate of 30 units per year beginning in Year 2, aiming for completion of the entire project by Year 5.

There will be strong interaction between this program and the other five programs of SPSS described below. There will be heavy overlap between the curriculum of the Learning Resources units and the curriculum presented at the national workshops, although the level of sophistication will differ. The Learning Resources units will include coverage of Place-Based Search, a topic that is entirely undocumented in textbooks at this time. They will include coverage of the principles behind the Software Tools we propose to develop. They will benefit from discussions and experience within the Virtual Community. Finally, we will include documented Best-Practice Examples as these are completed.

National Workshops

Our second strategy for inducing systemic change in the social and behavioral sciences will be based on intensive workshops, aimed primarily at junior faculty and graduate students but also including senior faculty. In today's academic world there are relatively few opportunities for sustained interaction and learning in residential settings; yet such interactions are extremely valuable in stimulating interest, and building working relationships and collaborations. They can also be effective ways of leveraging limited funding if participants undertake to promote workshop ideas when they return home, through new courses, application of tools obtained at the workshop, or proposals for funding.

Workshops of this nature were much more common three decades ago. An NSF-funded workshop held at the University of Iowa in 1973 on new ideas in location theory is widely remembered as formative by its participants, and one of its key successes was the donation of a package of software tools to every participant (Rushton *et al.* 1973). More recently, NCGIA co-organized two such workshops under the NSF-European Science Foundation GISDATA program. Each workshop included 40 participants, mixing junior and senior scholars drawn from both sides of the Atlantic. Also, Anselin has offered workshops in spatial data analysis and GIS through the Institute for Social Research at the University of Michigan every summer since 1995; these workshops have attracted interest from a broad spectrum of social and behavioral scientists, and have been heavily over-subscribed.

We propose to organize a series of workshops covering the principles and practice of spatially enabled social science. We propose to offer up to four per year, during the summer months and starting in Year 1, at locations distributed around the U.S. Participation will be by open competition, following advertisement on the WWW, in newsletters of all of the social and behavioral science disciplines, and in selected electronic news and discussion groups. Workshops will provide access to tools, and will include exercises in their use, as well as description and discussion of best-practice examples. Each workshop will last one week, and will include ample time for socializing and open discussion, in order to create a residential, participatory atmosphere.

Participants will be selected according to a mix of the following criteria:

- Preference for young scholars, including tenure-track faculty who have yet to receive tenure; PhD students advanced to candidacy; and people in post-doctoral research positions.
- The need to increase participation by traditionally under-represented groups.
- A maximum of 20 participants, with 1:1 access to computers.

- A statement submitted with the application addressing the question of leverage, through planned new courses, proposed research, proposed collaborations with others, and other indicators that the benefits of participation will accrue to as many other social scientists as possible.

Participants will be expected to pay a fee sufficient to cover expenses, including accommodation, and to cover their own travel expenses. We have budgeted for a number of scholarships to defray these costs partially, and expect that institutions will be willing to provide partial support for their participants also.

The Executive Committee (with oversight from the Science Advisory Board) will select topics for inclusion in the workshops, and will organize a small group of scholars to develop a set of instructional materials (including tools and best practice examples). These instructional materials will form the core for each workshop. In addition to Anselin's existing workshop material on analysis in the presence of spatial effects, we anticipate that three new workshop topics will be developed during each of the first three years, yielding a total of ten workshop topics. These topics might include exploratory spatial data analysis, spatial econometrics, spatial interaction theory, agent-based spatial modeling, geographic information systems, place-based search, spatial data modeling, or explicit spatial theory. Up to four workshops will be offered per year, mixing topics from among the ten, and taught by instructors selected by the Executive Committee from among the experts in spatially enabled social science. Each instructor will be compensated a fraction of a summer month. The workshops will draw from the core materials developed at the Center, but allow for some variation in personal style and approach. Teaching materials will also be made available on the WWW, integrated with the Learning Resources program, and made available through the Virtual Community program.

Best-Practice Examples

Our third strategy for building a collaborative, spatially enabled social science will focus on the development of a series of examples of best practice, and their widespread dissemination. These will range from inductive, exploratory research that leads to new theory, to deductive, theory-driven research that advances our understanding through theory formulation or empirical test. Examples could include use of spatial analysis, modeling and simulation in spatial context, addition of space to theory, explicit treatment of space in policy, spatial decision support, or any combination of these. In all cases, our criteria for selection will be based on:

- demonstrable and compelling new insights gained using a spatial approach;
- coverage of the full range of the social and behavioral sciences;
- support for under-represented groups;
- demonstration of the potential of a spatial approach to integrate across disciplines and paradigms.

The examples developed through this program will be documented and published in disciplinary journals. In addition, we will incorporate them into both the Learning Resources and the National Workshops, at appropriate levels of sophistication. We will also encapsulate them in a monograph, to be published by a reputable publisher in Year 5.

We will conduct this program through grants to individuals or groups of social scientists. Each grant will provide for up to one summer month's salary for an investigator, and research assistance from a graduate student for one summer. Each September we will announce an annual competition, through disciplinary newsletters, the WWW, and selected electronic discussion lists and news groups. Interested scholars will be asked to submit a research proposal due in December, which will be evaluated by the SPSS Science Board with input from external peers. Each year's final recommendations will be submitted to NSF for approval. Awards will be made in February of each year, for research to be conducted the following summer, and final reports will be due in November.

Place-Based Search

The World Wide Web has been enormously successful at providing access to certain kinds of information, and at facilitating information's widespread and rapid dissemination. The Web has been compared to a library, and indeed the total amount of information accessible via the Web already greatly exceeds the amount accessible in any of our major research libraries. But although the Web is powerful in many respects, it remains far inferior to libraries in its lack of quality control and assurance (the Web equivalent of the publisher's peer review and the collection-building services of libraries) and of comprehensive abstracting and cataloging. The search engines (Yahoo, Lycos, Altavista) provide primitive machine-generated catalogs, but are limited by their almost exclusive focus on textual information, and by their crude mechanisms for selecting key words.

A spatially enabled social science will require mechanisms for finding information about places, or *Place-Based Search*. We define information as *geo-referenced* if it is associated with one or more locations, or a *footprint*, on the Earth's surface. Place-Based Search supports the finding of information based on a defined footprint, specified either in geographic coordinates or by reference to one or more placenames. Such searches should also be refinable by date, subject, or other suitable characteristics.

Many efforts are currently under way to develop support for Place-Based Search, but none is specifically targeted to the unique problems of the social and behavioral sciences. For example, the U.S. Environmental Protection Agency offers search of its information resources based on ZIP code (http://www.epa.gov/enviro/zipcode_js.html). The Alexandria Digital Library (alexandria.ucsba.edu) provides the services of a large map and imagery library over the WWW. But at this time no site addresses the needs of social and behavioral scientists interested in obtaining information about a place.

We propose to develop such facilities for Place-Based Search. They will include:

- Development of a WWW site providing pointers to sources of information based on place, such as major Federal agency information sites where Place-Based Search is supported.
- Development of a unified *gazetteer* for the social and behavioral sciences, providing the means to link placenames to geographic coordinates. It will include placenames and reporting zones used in major information sources such as the Census, together with the means to integrate data based on different geographic zones. We will collaborate in this effort with major repositories of social and behavioral data, such as ICPSR.
- Collaboration with major catalog organizations, including OCLC, to enable Place-Based Search of library catalogs. It is estimated that 30% of the holdings of major libraries such as that of the UC System are in some way referenced to place, but mechanisms to search systematically based on place are lacking. We will adapt the existing interface of the Alexandria Digital Library to enable search over conventional library catalogs.

Software Tools

Tools to enable a spatial approach to social science have emerged rapidly in the past decade, and a flourishing software industry is now supported in part by social science applications. The tools include GIS, ranging from easy-to-use packages like ArcView and Map/Info to "industrial strength" workhorses like ARC/INFO; statistical packages such as S-Plus with substantial spatial functionality; simpler packages for mapping; specialized packages for transportation analysis; and packages to support data collection in the field. In general, two issues seem of paramount importance in determining whether such tools serve the needs of the social and behavioral sciences:

- How accessible are they to non-experts? Are they relatively unfriendly, and thus useful only to scientists with a high level of specialization in the field, or are they relatively user-friendly, and capable of encouraging users to experiment, and to learn more?

- Are they produced by the private-sector software industry or by individuals or institutes in the academic sector? If the former, are the social and behavioral sciences important to the producer as an application, or is the product's design driven by an application with substantially different needs?

With respect to these two issues, we contend that many of the tools available to a spatially enabled social science at this time are either:

- Products of individuals or institutes in the public sector, and designed for scientists with a high level of specialization (cheap but not user-friendly), or
- Commercial off-the-shelf (COTS) products for which the academic market is a secondary application (user friendly, inexpensive, but not powerful).

We believe that a spatially enabled social science will require a new kind of tool, capable of powerful analysis, but comparatively accessible, extensible, and user-friendly.

We propose to build a new set of tools based on the spatial statistical suite known as SpaceStat (Anselin 1992). The original emphasis in SpaceStat was to develop a proof of concept for software to carry out regression analysis in the presence of spatial effects, specifically spatial heterogeneity and spatial dependence, which render the stationarity and independence assumptions of traditional econometric analysis invalid in a spatial context (Anselin 1989). Specifically, SpaceStat initially implemented all the spatial econometric estimation and specification tests covered by Anselin (1988). The package has been expanded considerably since its first incarnation and now (Version 1.90) includes exploratory spatial data analysis as well as links to commercial GIS such as ArcView. The SpaceStat package has been developed over a period of many years by Anselin, and is currently marketed by BioMedware (www.spacestat.com). The software has several hundreds of users at over 100 universities in more than 20 countries.

The demonstrated success of SpaceStat has shown the existence of a growing demand for software tools to tackle spatial data. However, SpaceStat is based on a design that is more than ten years old and modern users increasingly insist on a friendly point-and-click environment. We therefore propose to redesign and develop SpaceStat into a modern suite of modular and highly user-friendly software for the exploration and analysis of spatial data. Specifically, we suggest that major efforts are needed in the following four areas:

- Increased support for *exploratory spatial data analysis* (ESDA, see, for example, Anselin 1998, 1999) tightly integrated with the data models of a GIS. ESDA mirrors the trend in statistics to a more exploratory, intuitive, and graphical approach to analysis that began in the 1970s (Tukey 1977). ESDA tools allow the researcher to explore data for pattern, anomalies and outliers, correlations, and other aids to the formulation of hypotheses. The new tools will allow data to be explored simultaneously from several different perspectives (table, scatterplot, map), or at several different levels of spatial aggregation. To date there have been a small number of isolated (academic) efforts to build tools for ESDA in a GIS environment (e.g., Bao *et al.* 1999, Symanzik *et al.* 1998), but these have tended to be very technique-specific and not well integrated with other forms of spatial analysis. We will build on the initial approach outlined by Anselin (1998) and Anselin and Smirnov (1998) which has been implemented as an extension to the ArcView software. We will extend this to an open, object-oriented and modular environment for data visualization and exploration capable of handling very large data sets. This will involve not only a simple porting of existing code, but methodological development and algorithm refinement as well.
- An intuitive graphical *user interface*. The current interface is clearly dated and may inhibit less-computer-literate users. The application of modern object-oriented interface design tools will yield an entry to the methods that will be more intuitive and thus more accessible to a larger community of users.
- An *open and modular architecture*. The current architecture of SpaceStat is closed and only

sophisticated computer programmers are able to extend its functionality. A redesign of SpaceStat as a suite of software components that could be used either in combination with a user interface or independently would greatly leverage its current functionality and allow it to be incorporated in special-purpose software needed by researchers for specific (as opposed to generic) analyses. Hence researchers in the social sciences who develop new methods or very unique applications could take advantage of the substantial existing functionality of SpaceStat and focus their resources on adding the specialized tools they need. Our Virtual Community program will provide the context that will make this possible.

- Modules for *advanced spatial econometric techniques*. Recent theoretical advances in social science research have stimulated a demand for techniques that can handle spatial dependence and spatial heterogeneity in contexts other than linear regression models. Very few tools currently exist to tackle such spatial effects in count data, discrete choice data, panel data and the like, which have become the main empirical basis for modern analysis. Taking advantage of the new open environment in SpaceStat will allow us to develop advanced modules to deal with limited dependent variables and space-time data. Following the component paradigm, these modules will have a well-documented interface which will allow their inclusion in other software environments.
- Modules to implement *other methods* recently developed by spatial statisticians and with potential relevance to the social and behavioral sciences. These will include recent contributions adding spatial richness to popular Bayesian methods (e.g., Besag *et al.* 1995, Gilks *et al.* 1996).

We propose to develop the new generation SpaceStat software in close collaboration with Environmental Systems Research Institute (ESRI; letter of commitment in Section I). We will design a new suite of tools using component technology, and implement them in an open, modular form suitable for access via the WWW. The tools will be fully compatible with ESRI's other products, including ArcView, MapObjects, and ARC/INFO v8. In this way we will enable social scientists to achieve a much higher level of sophistication in their analyses of spatial data than is currently possible using COTS tools such as ArcView.

The development will be carried out by a research team at UTD under the direction of Anselin and in close collaboration with David Maguire, Director of Product Planning at ESRI. ESRI will contribute a software engineer to the team who will have main responsibility for the actual code development. Overall design, methodological development and algorithm refinement will be carried out at UTD. This effort will take three years, with Year 1 focused on requirements analysis, design and prototype development, Year 2 on software coding and testing, and Year 3 on refinement, beta testing and writing of user's guides and on-line manuals. This will parallel the development of the advanced modules, which will be carried out at UTD.

Virtual Community

Our final strategy for building a community of spatially enabled social scientists will use the tools of the Internet to facilitate a Virtual Community. We believe that the ability to tap *active support services* will be critical, and propose to make technical and methodological advice available online. We also believe that a community will to some extent build itself, if it is able to interact effectively through electronic means. Thus we propose to build a central WWW site that will offer the following:

- Access to the other SPESS programs: Learning Resources, information about National Workshops, Best-Practice Examples, Place-Based Search, and Software Tools.
- Information about other activities nationally and internationally that are likely to be of interest to the community.
- Links to other sites offering services relevant to SPESS, including vendors of COTS software, data repositories, courseware, discussion groups, societies, and bulletin boards. We will collaborate with

ESRI as they develop their Virtual Campus to better meet the needs of social and behavioral scientists.

- An *advice hot-line*, moderated by graduate students, who will answer questions, and direct inquiries to more knowledgeable sources.
- *Push* services to individual users who select particular types of information. Any new information available to SPESS and meeting these individual criteria will be sent automatically.

In addition to these WWW-based services, we will promote SPESS as a focus for sharing software objects for spatially enabled social science. We will make the protocols and standards underlying the Software Tools that we develop widely available, and encourage others to contribute their own tools consistent with these. In the past, this model has worked extremely well in building an active software-sharing community around such nuclei as GRASS (a GIS originally developed by the Army Corps of Engineers in the 1980s), and the Linux operating system.

MANAGEMENT

SPESS will be managed by a small but effective set of individuals and committees. Primary responsibility for oversight will be assigned to a Science Advisory Board, composed of approximately 15 prominent social and behavioral scientists from across the full range of disciplines. The Board will meet twice a year, to review all Center activities and to report to the Executive Committee and NSF. They will make the final recommendations for Best Practice Awards to be forwarded to NSF. We propose subject to NSF approval to invite Brian Berry (University of Texas at Dallas), a prominent social scientist and member of the National Academy of Sciences (currently a member of the NAS Council), to chair the Board. Other members will be nominated by the Executive Committee and submitted to NSF for approval.

Day-to-day management will be the responsibility of an Executive Committee, composed of the PIs (Goodchild, Anselin, and Appelbaum), senior researchers (Smith, Sweeney, and Couclelis), and the Project Manager. They will confer at least once a month, in person or by teleconference.

Center staff at UCSB will include a Project Manager with day-to-day responsibility for the Center's programs; an Executive Assistant with responsibility for office management, committee meetings, and visitors; a part-time Workshops Coordinator to make arrangements for the National Workshops; and a full-time Webmaster.

EVALUATION

With a project such as this that is aimed at achieving systemic change within a broad range of disciplines, it is particularly important that evaluation be based on *outcomes*. The following table shows our goals for each year of the project, the outcomes that are desirable, and the outcomes that we will regard as minimal indicators of success. In the table, G=general, LR=Learning Resources, NW=National Workshops, BPE=Best-Practice Examples, PBS=Place-Based Search, ST=Software Tools, VC=Virtual Community. Programs whose goals and outcomes are identical to those of the previous year are omitted.

Yr		Goals	Desirable Outcomes	Minimal Outcomes
1	G	Complete Center management structure and publicize its existence widely	High level of awareness of Center among all social and behavioral sciences	Awareness among selected disciplines only
	LR	Form advisory committee, outline content, complete first units	30 units completed, 1,000 accesses per month on WWW site	15 units completed, 100 accesses per month

2	NW	Begin development of workshop topics, organize first round of workshops	3 new topics completed, 2 workshops completed	1 new topic completed, 1 workshop completed
	BPE	Publicize program and process first round of applications	High level of awareness of program among all social and behavioral sciences	Awareness of program in selected disciplines only
	PBS	Assess requirements and existing capabilities	Complete assessment	Partial assessment
	ST	Design software and complete prototype	Complete prototype	Prototype completed with limited functionality
	VC	Develop community infrastructure	1,000 accesses per month for information from 100 active participants	100 accesses per month from 30 active participants
	G	Program as a whole is successful	Successful oversight review, widespread awareness of Center's programs	Critical suggestions from oversight review successfully implemented
3	LR	Develop new units	Annual target completed, WWW accesses grow by 50%	WWW accesses grow by 25%
	NW	Complete annual workshops and new topics	Demand for courses grows by 50%; positive reviews by participants	Demand for courses grows by 10%; mixed reviews by participants lead to corrections
	BPE	Make annual target of awards	Annual target met	2 new awards made
	PBS	Complete WWW site	1,000 accesses per month redirected to sites offering place-based search	100 accesses per month
	ST	Code new tools	Entire design coded	50% of design coded
	VC	Continue growth of community	Accesses per month grow by 50%, active participants by 50%	Numbers of accesses and participants grow by 20%
4	PBS	Complete assembly of gazetteer	Successful implementation of all requirements identified in Year 1	Successful implementation of 50% of requirements
	ST	Complete beta testing and documentation of tools	Testing completed, dissemination program begun	Testing completed
5	PBS	Complete spatial indexing of major catalogs	Successful indexing of two major catalogs	Successful indexing of one major catalog
	ST	Make tools widely available	User community of 1,000	User community of 100
5	LR	Complete program	Stable WWW site contains 100 units and receives 10,000 hits per month	80 units complete, 2,000 hits per month
	NW	Complete program	Survey of participants shows uniformly positive outcomes	Survey of participants shows predominantly positive outcomes
	BPE	Complete program	Results of all awards peer reviewed and published	Results of 80% of awards published after peer review

		reviewed and published	published after peer review
PBS	Complete integration with Alexandria Digital Library	100% successful integration	Partial integration
VC	Ensure continuation of program	Continuation ensured	Continuation ensured

RESULTS OF PRIOR SUPPORT

Goodchild

Collaborative Agreement SES 88-10917 between NSF and the University of California, Santa Barbara (with subcontracts to the University at Buffalo and the University of Maine) provided funding for the National Center for Geographic Information and Analysis through the end of 1996, with a no-cost extension through 1997. Its objectives were to conduct research in geographic analysis utilizing geographic information systems (GIS); to promote the use of GIS throughout the sciences; to increase the nation's supply of experts in GIS; and to provide a national focus of research, with links to related efforts in other countries. Goodchild was PI on this award. Under this award NCGIA researchers addressed 18 topics, known as Research Initiatives; published 54 books, 646 refereed journal articles, and 734 other articles, and gave 1006 research presentations; developed extensive materials in support of instruction at all educational levels, including the 1990 NCGIA Core Curriculum in GIS; developed and distributed software and data sets; and organized successful international conferences in rapidly advancing areas of research.

The Varenus project, NCGIA's project to advance geographic information science, was initiated in 1997 under Cooperative Agreement SBR 96-00465, with subcontracts to the University at Buffalo, the University of Maine, and the University of Minnesota, and with Goodchild as PI. The Varenus effort is organized into three Strategic Research Areas, each with a panel of internationally known experts: cognitive models of geographic space; computational implementations of geographic concepts; and geographies of the information society. An Advisory Board oversees the entire project. During the period of the award (2/1/97–1/31/00) a total of nine Specialist Meetings will be held, three on topics of the highest priority in each of the three Strategic Research Areas. Each meeting includes approximately 30 scholars, drawn from all of the disciplines relevant to the topic by an international process of open selection and invitation. Eight of the meetings had been held by the time of submission of this proposal. Following each meeting, continued collaboration is promoted by programs of seed grants and visiting fellowships. Each Varenus meeting results in a report summarizing the state of knowledge in the area and prioritizing a multiyear research agenda. It also results frequently in substantial redirection of the interests and collaborative links of the participants, thus helping to advance GIScience.

Anselin

Award SBR 9410612, titled "New Methods for the Exploratory Analysis of Geographical Data", focused on the methodological development, software implementation, and application of a test for local spatial association, referred to as the Local Moran statistic. Methodological developments dealt with the extension of this statistic to space-time data and rate variables, for which a number of standardization and smoothing procedures led to improved performance. Also, the visualization of this statistic and its linkage to other statistical graphics was explored in a software integration with a popular GIS package (ArcView) and incorporated in the latest version of the SpaceStat software package and its Extension for ArcView. The new methods of exploratory spatial data analysis (ESDA) were applied to the analysis of spatial clusters and the detection of spatial outliers in a number of investigations, ranging from the clustering of crime and disease incidence, to the location of underserved mortgage areas in urban

neighborhoods, to the assessment of spatial equity and the evolution of trading blocs. The applications illustrate the power of the methods to suggest and indicate patterns in the data in conjunction with GIS and mapping software. The project led directly to twelve published pieces so far: four refereed journal articles, five book chapters, two proceedings articles, and one technical report. In addition, four other papers have been submitted or have been prepared for submission. The project also yielded one doctoral dissertation (Oleg Smirnov) and supported one pre-doctoral fellow. Finally, the findings of the research carried out as part of the project were presented at more than twenty scholarly conferences, workshops, and departmental seminars. In addition, the new methods form an integral part of a course on spatial data analysis and GIS taught for the past four summers as part of the Interuniversity Consortium on Political and Social Research (ICPSR) Summer Institute on Quantitative Methods at the University of Michigan.

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