THEORIZING WITH GIS: A TOOL FOR CRITICAL GEOGRAPHIES?

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ABSTRACT

This article explores the potential of using GIS in qualitative research by disentangling the seemingly rigid association of the field of geographic information science with quantitative geography. I examine the opposition between quantitative and qualitative methods as an extension of different epistemologies and not their innate incompatibility and re-position GIS within these methods seen as a continuum. I show that the always assumed alignment of GIS with quantitative research has never been complete and the many openings in GIS enable qualitative research. I also discuss how critical geographers can engage with and transform GIS as well as enhance their explanations and social theory in general by representing spatially complex social processes and relationships.

INTRODUCTION

This article explores the potential of using GIS in qualitative research by disentangling the seemingly rigid association of the field of geographic information science with quantitative geography. Representing positivist geographic tradition, the mainstream GIS caught attention of critical geographers in the 1990s (Schuurman 2001). First controversial (e.g., Sheppard 1993; Pickles 1995a) and continuously innovative (Schuurman and Kwan 2004), the encounters between these oppositional practices of knowledge production have resulted in new enticing and dynamic critical GIS research. The relationship of qualitative research and GIS is among such new and recent developments (Rocheleau 1995; Matthews et al. 2001; Sheppard 2001; Kwan 2002a, b; Pavlovskaya 2002; Bell and Reed 2004; other contributions to this issue).

While today GIS sustains an industry with a $6 billion a year value (Clarke 1999, p. 6, also see Flowerdew 1998) and remains a corporate and state-sponsored technology widely used for profit making and control (Pickles 1995b; Goss 1995; Clark 1998; Crampton 2003), critical GIS scholars have aspired to change this status quo (Sheppard 2001). Even "as is," they have shown, GIS has been used outside corporate and government contexts, by those in unequal power positions, and to advocate their needs. For example, public participation GIS (PPGIS) has gained an extremely broad audience focusing on the role of GIS in grass-roots movements and neighborhood struggles (Craig et al. 2002; Elwood and Leitner 1998; Clark 1998); counter mapping has become a strategy of resistance and postcolonial empowerment (Rundstrom 1995; Weiner et al. 1995; Dorling 1998; Clark 1998; Lewis 1998); GIS has been used as an analytical tool in critical research on capitalism (St.Martin 2001; Graves 2003; Pavlovskaya 2004); feminist scholars have disclosed the masculinist bias of GIS and attempted to redefine GIS through its use within feminist epistemologies (Huffman, 1997; Hanson 1997, 2002; Kwan 1999a, b, 2002a,b; McLafferty 2002; Schuurman 2002; Schuurman and Pratt 2002; Pavlovskaya 2002, 2004); and post-structuralist research has showed how GIS discourses shape our worlds by supporting select representations of people, places, and processes (Harvey and Chrisman 1998; Yapa 1998; Robbins and Maddock 2000; Pavlovskaya 2002).

Critical GIS research has also emphasized that this technology is always constituted by social processes and power dynamics surrounding its development, adoption, and applications. Moreover, as this article demonstrates, GIS is not fixed and given but is constantly remade through the politics of its use, critical histories of it, and the interrogation of concepts that underlay its design, data definition, collection, and analysis. In other words, futures of GIS are contested and openings exist for new meanings, uses, and effects.

More specifically, this article interrogates a prominent aspect of GIS' status quo - the association with quantitative analysis - and uncovers its potential for qualitative research. The first part examines the opposition between quantitative and qualitative methods as an extension of different epistemologies and not their innate incompatibility. In the second part I reconsider the seemingly profound differences between these methods and show that based on their contribution to scientific research they form a continuum. Re-positioning GIS as neither a quantitative or qualitative tool but a method open to reconceptualization in the third part disrupts the assumed complete alignment of GIS with quantitative geography and creates the openings that enable GIS use with qualitative research. Finally, in the fourth part I point to some ways in which critical geographers can engage with and transform GIS. Theorizing with GIS would enhance critical geographic explanations and social theory in general.

METHODS ACROSS EPISTEMOLOGIES?

The Dictionary of Human Geography defines quantitative research methods as "the use of mathematical techniques, theorems, and proofs in understanding geographical forms and relations" (Barnes 2000b, p. 663) while qualitative methods are "a set of tools developed to pursue the epistemological mandate of philosophies of meaning" (Smith 2000, p. 660). If both systematic knowledge and meaning are important for understanding complex human worlds, these two approaches to knowledge production are not mutually exclusive but different ways to do research.

The oppositional representation of these methods, however, has long existed in social sciences and human geography (Cloke et al. 1991; Philip 1998; Philo et al. 1998; Openshaw 1998; Flowerdew 1998) but today their relationship is changing. Although quantitative techniques continue to dominate publications in major geography research journals (Flowerdew 1998) and major textbooks (such as Nachiamas and Frankfort-Nachimas 2000 in social sciences; Cadwallader 1996 in urban geography), using qualitative methods no longer requires thorough justification (Crang 2002) and their prominence in the newest methodological texts has increased (for example, Babbie 2000; Creswell 2003; in geography Clifford and Valentine 2003; Robinson 1998). Some even believe that it is quantitative geography that is in danger of becoming moribund and link its revival to GIS (Openshaw 1998; Flowerdew 1998; Schuurman 1999; Johnston 2000; Sheppard 2001). In short, both quantitative and qualitative methods occupy solid positions today. Yet, the debate in geography over their role continues and remains infused with passion (for its newest round in economic geography see Amin and Thrift 2000, Plummer and Sheppard 2001).

This section briefly addresses one development that emerged from this debate - the destabilization of the assumed hard links between method and epistemology. Adding to this destabilization, I reconsider the seemingly profound differences between quantitative and qualitative methods in their contribution to scientific knowledge. I show that, contrary to common perceptions, these methods are not easily differentiated in terms of analytical power, theoretical advancement, and scientific rigor. Therefore, firmly placing GIS in one (quantitative) group is misleading. A critical examination of quantitative and qualitative potential of GIS itself follows later in the article.

METHOD AS POWER RELATION

Context, politics, and power dynamics in academic research have played a crucial role in producing epistemological and related methodological divisions. Political economic, feminist, and post-structuralist epistemological critiques of the scientific method helped rethink its authority (Poon 2004) but they also had an essentializing effect on quantitative and qualitative research (Dixon and Jones III 1996). The reason is that epistemological categories, including meanings of qualitative and quantitative research, are imbued with relations of social power that "enable and are derived from the organizational structure and differential deployment" of these categories that "in turn, fashion the boundaries of the disciplinary knowledge" (Dixon and Jones III 1996, p.767; also see Dixon and Jones III 2004). These dynamics dichotomize the difference and make it hierarchical. They also homogenize the two groups of methods and construct them as producing incompatible and mutually exclusive knowledges.

Besides the flaws of positivism, quantitative methods were also exposed as connected to and supporting conservative social ontologies such as the neo-classical capitalism, patriarchy, imperialism, and social control in general (Cloke et al. 1991; Pete 1998; Livingstone 1992; Harvey 1973; McDowell 1992; Godlewska and Smith 1994). Qualitative methods, at the same time, have become an accepted strategy for those advocating non-positivist knowledge production and aspiring emancipatory change. The questions of methodology, therefore, have become wrapped not only with the tantalizing questions of ontology and epistemology but also with no less tantalizing questions of different political commitments of academics. In this light, choosing quantitative or qualitative methodology could not remain simply a choice of a "tool box" (Lawson

1995). Instead, it had to be a single answer to all the important questions, from the nature of reality to future of humankind and personal politics. The gulf between quantitative and qualitative approaches in human geography could not had been wider.

BREAKING THE LINKS

In the last decade, however, critical geographers revisited the usefulness of quantitative methods (McLafferty 1995; Lawson 1995; Philip 1998; Plummer et al. 1998; Sheppard 2001; Plummer 2000). Rejecting all or some of the foundations of positivism such as claims to objectivity, the existence of order or the ability to truly mirror this order, they conclude, should not necessarily preclude using quantitative techniques reflectively, pragmatically, and with understanding their limited applicability. As Dixon and Jones III (1998) explain, employing counting by feminists and Marxists, for example, is possible to a degree that they share a positivist assumption that a certain social order exists, as in critical realist analyses of patriarchy and capitalism. Vicky Lawson (1995) shows that quantitative methods also are variously embedded with the positivist assumptions making some of them (like descriptive statistics) more amenable to feminist research. Furthermore, quantitative language retains authority in academic and policy worlds that maybe strategically important when advocating from alternative perspectives or representing the interests of disempowered social groups (McLafferty 1995; Sheppard 2001).

Quantitative geographers, on their part, have recently become more open to post-structuralist criticisms of positivism (interestingly skipping earlier but similar Marxian and feminist critiques) and, in addition to "reducing" scientific ambitions and renouncing the methodological chasm, they began advocating statistical, analytical, and modeling methods that are more sensitive to local context, complexity, dynamism, and openness of socio-spatial processes (Fotheringham 1997, Poon 2004).

Moving further, researchers began analyzing processes that have led to the construction of the very opposition between the two methodologies (Rocheleau 1995; Lawson 1995; Philip 1998; Barnes 1998, 2000a, 2001a; Sheppard 2001). Recent work in history of science has shown that the development of modern scientific practices based on mathematics and statistics as well as their diffusion into geography in the 1950s had not been a result of their self-actualizing innate rationality but a product of specific historical and cultural context, including social, economic, political and personal circumstances of researchers that all led sciences in a particular direction (Livingstone 1992; Barnes 1998, 2001a, 2003; Hepple 1998; Sheppard 2001; Barnes and Hannah 2001). Within this perspective, the hegemony of quantitative methods and the concomitant construction of qualitative methods as non-scientific is also a cultural product, a defining development in modern science but yet a historically contingent moment.

Also, it was realized that qualitative techniques have been routinely used within the mainstream, predominantly quantitative, research (Philips 1998; Tashakkori and Teddlie, 1998, 2002) but their role was little acknowledged or presented as secondary to the major quantitative project. Examples include using focus groups to develop structured surveys and qualitative information about subjects and places, personal observations and pilot interviews to formulate hypotheses. Overall, the link between epistemologies and their methods has become looser.

MIXING METHODS

Further disentangling the link, a growing literature on the so-called "mixed methods" explicitly makes a case for combining quantitative and qualitative techniques and the number of such projects has grown exponentially (Rocheleau 1995; Tashakatori and Teddlie 1998, 2002; Philip 1998; Cope 1998; Winchester 1999; Creswell 2003). In such designs, both techniques are used simultaneously or at different stages within a single project.

Tashakkori and Teddlie (1998) state that in the mainstream social sciences mixed methods gained legitimation within the so-called pragmatist paradigm that places practical considerations above ontological and epistemological beliefs (i.e., how world is organized, how we can understand this order, and to what end) and makes related power dynamics irrelevant.[1] Geographers have also explored the potential of pragmatism (Wescoat 1992; Barnes 1996; Gibson-Graham 1996, 2000), but mixed methods have

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[1] In accounts linked to Richard Rorty, however, modern pragmatism is not indifferent to foundationalist theories of knowledge but offers a different epistemology consonant with post-structuralist thought (Gibson-Graham 2000). This is not that the truth no longer matters but finding an appropriate method to establish a single truth is irrelevant. The social context, power relations, and political commitments gain importance because they enable particular epistemologies and thus affect research practice and its transformative-emancipatory role (Gibson-Graham 1996, 2000; Creswell 2003).

received attention within many philosophical frameworks (Rocheleau 1995; Lawson 1995; McLafferty 1995; Winchester 1999; Kwan 2002; Pavlovskaya 2002).

For example, feminist geographers call for reflexivity and value qualitative methods but also reclaim quantitative analysis (Lawson 1995; McLafferty 1995; Hanson and Pratt 1995). Similarly, Marxist geographers advocate qualitative research and the "cultural turn" in economic geography (Amin and Thrift 2000; Barnes 2001b) but no longer dismiss quantitative methods (Plummer et al. 1998; Plummer 2000; Sheppard 2001; Plummer and Sheppard 2001). Post-structural geographers do not reject these methods either but interrogate research practices that employ quantitative approach (Dixon and Jones III 1996; Barnes 1996, 1998, 2000a, 2001a, 2003; Gibson-Graham 1996). While quantitative geographers have begun rethinking their epistemological privilege, non-positivist geographers have expanded their methodological choice.

QUANTITATIVE / QUALITATIVE AS CONTINUUM

Despite all these developments, a boundary still divides these two sets of methods and this division continues to homogenize and essentialize their content. Geographers keep equating quantitative methods with advanced statistical and spatial, and, therefore, scientific analysis (Sheppard 2001) and qualitative methods with "a mix of coffee room discourse, vendor sales hype, informal social interviews with one or two people, and an active imagination" (Openshaw 1998, p.321). It is not uncommon to discuss these methods in terms of their superiority over each other (Openshaw 1991, 1998) and the question about their fundamental incompatibility within a singular theoretical framework is still debated (Jones III and Dixon 1998).

The growing exploration of mixed methods in geography, however, calls to move beyond the debate over the applicability of specific methods within particular research traditions toward a more profound deconstruction of the categories of quantitative and qualitative themselves. Inscribing them with the new meanings remains an important and largely unfulfilled task. Below I show that the clear-cut difference between these methods is not substantiated not only because the techniques in both groups have already been employed in many epistemological contexts (as demonstrated above) but also because they form a methodological continuum in terms of their contribution to scientific explanation.

First, the association of quantitative methods with rational reasoning and qualitative methods with lack of rationality and logic is misconstrued. In his "placed" history of locational analysis, Trevor Barnes (2003) shows that any moment in the development of these techniques by von Thünen, Weber, and Lösch, - the techniques that stand for rationality, mathematical rigor, abstract thinking, and theoretical insight into spatial order, - was in fact compounded not only by their personal histories and social context of the time, but also by their political views, emotions, and feelings about the places they new the best. The rational location theory, then, is always also irrational, non-mathematical, and place-bound. Barnes' deconstruction of justifications for the use of quantitative methods in geography (1994), histories of correlation and regression (1998) and accounts of quantitative geography (1994, 1996, 2000a, 2001a) also demonstrate that apart from scientific rationality, they all are place and time bound developments infused with personalities and social commitments of their inventors and promoters.

At the same time, modern techniques for qualitative analysis, despite their concern with meaning, representation, and explanation, are based on the systematic detection of underlying "concepts" and "patterns" in texts used as evidence (see Miles and Huberman 1994; Strauss 1995). This approach to qualitative information is extremely rational and logical and, actually, reminds one of factor analysis. Coding interview texts, too, is no less an intense analytical procedure than defining statistical variables and their relationships. Deconstruction as a post-structuralist method is successful also because of its powerful coherence and logic (Barnes 1994; Jones III and Dixon 1998). In other words, both types of methods bear elements of rationality and non-rational influences.

Second, quantitative methods are often thought of being sophisticated and difficult to use while qualitative methods are somehow simple and easy to use. In our minds quantitative analysis usually stands for advanced statistics but under its umbrella we often find such techniques as differencing, simple regression, basic geometry, calculation of the mean, counting totals, or plotting data for visualization. Academics and practitioners most commonly use these simple tools but when called "quantitative" they acquire the authority of science. Qualitative methods, too, range from personal observations and field notes to intense theory development and deconstruction based on the synthesis of literature or findings from other studies. But even the most sophisticated analytical procedures, once termed qualitative, loose their scientific status to become "coffee-table talk." Both types of methods, however, can be simple or advanced.

Third, although qualitative research shares some problems of sampling and recruiting subjects with quantitative research, it has unique challenges because qualitative data is often created from scratch. In particular, choice of informants is crucial because their number is usually smaller than in large survey projects but they must have the appropriate knowledge and experience. This research requires superior interviewing skills, enormous time, financial, and labor resources for interviewing, transcribing, (often) translating, coding, and analyzing the interviews. In the end, these methods demand no less but different expertise and arguably more labor and resources than running regressions on the already existing census datasets.

Forth, the scientific rigor of quantitative methods stems from their assumed ability to deal with complexity by dividing it into its constitutive elements, quantifying them, and then linking them together in a mathematical or statistical model. Although these tasks sometimes require in-depth knowledge of mathematics and statistics, the resulting models are often very simple representations of reality. Often, such unavoidable simplification is dissatisfying to the researchers who developed the models (as was the case with Weber and Lösch, according to Barnes 2003) or attempt to replicate and use them (Plummer 2000). Qualitative methods, on the other hand, work to understand social worlds in their complexity and contradiction, although certain reduction is unavoidable. They "provide access to the motives, aspirations, and power relationships that account for how places, people, and events are made and represented" (Smith 2000, p. 660). Qualitative methods help uncover geographic processes that simply cannot be revealed by quantitative analysis alone (Crang 2002).

Fifth, and related to the previous point, the common perception remains that quantitative methods are theoretical while qualitative methods do not amount to theory development. Yet quantitative geographers often admit in passing that much of their work involves the statistical verification of hypotheses rather than the creation of new theories (Openshaw 1998; Flowerdew 1998; Sheppard 2001; Plummer 2000). To suit such verification, hypotheses must be simple statements that describe relationships only between a few variables. These conceptually small tasks have a little potential for a theoretical breakthrough. It is qualitative reasoning, however, that has produced path-breaking theories in social and physical sciences through synthesis of information (e.g., the theory of relativity, classical economics, the Marxian theory of value, the theory of patriarchy, and so on). Once created, the "qualitative models" may be verified empirically or modeled mathematically - if appropriate and possible. Even quantitative geographers (Poon 2004, p.812; Casetti (1999) cited in Poon 2004) admit (in a different context) that their methods "build logical structures of geographic explanations" that originate in non-quantitative "modes of inquiry" such as "textual" and "academic" (or qualitative research and analysis). The explanatory power of qualitative methods, however, originates in that they seek new understandings of how things work (Strauss 1995; Miles and Huberman 1994). Consequently, certain qualitative analytical techniques (e.g., grounded theory) specifically work to uncover the mechanisms that produce processes instead of measuring their manifested patterns (Strauss 1995).

Sixth, no clear line divides quantitative and qualitative methods based on empirical coverage and representativeness. Both types of research may use data derived from either hundreds or only a relatively small number of cases. While statistical analysis usually draws on large datasets, mathematical modeling is often all theoretical and "data free" (Openshaw 1998). Qualitative empirical research often focuses on a small sample because it is concerned with theoretical representativeness (not statistical) but may include a relatively large sample. Qualitative synthesis, at the same time, may not use any original data at all.

Finally, quantification implies precision and accuracy while qualitative research is associated with vagueness and lack of clarity. Yet they both can be sloppy or rigorous, poor or high quality, probing or intensely analytical - depending on the task as well as skills and ethics of a researcher.

In conclusion, if compared based on their analytical rigor, power of reasoning, empirical coverage, and depth of insight, the diverse qualitative and quantitative techniques form an analytical continuum. Thinking of these methods in terms of such continuum instead of two separate tool boxes opens the door for interrogating the assumed quantitative properties of GIS and re-envisioning it as part of this continuum.

EXCAVATING NON-QUANTITATIVE GIS

Simultaneously an outgrowth of quantitative geography and a versatile charismatic visual technology, GIS has uniquely internalized the dichotomies of positivism and critical geography and quantitative and qualitative research methods. Although the methodological debates in geography directly concern GIS, the discussion of its position relative to these methods has only recently started (Rocheleau 1995; Matthews et al. 2001; Kwan 2002; Pavlovskaya 2002; Bell and Reed 2004). Advancing this debate, I examine how the link between GIS and quantitative geography was produced through the dynamics similar to those that have previously drawn the boundary between the quantitative and qualitative methods. Then, I consider several openings in GIS that are moments which, in my opinion, further disrupt the quantitative and qualitative dichotomy and disassociate GIS from its quantitative end. Making GIS part of the quantitative/qualitative continuum, the openings show that GIS is already intimate with qualitative information and analysis and thus affirm its potential affinity with critical geographical explanations.

GIS MADE QUANTITATIVE

For its supporters and critics alike, GIS from its inception has been firmly rooted in the quantitative camp (Pickles 1995b; Openshaw, 1998; Flowerdew 1998; Sheppard 2001). In the eyes of most professors, students, and non-academic users GIS represents a computer-based vehicle loaded with scientific tools. GIS, many hope, would even revive quantitative academic geography (Openshaw 1998; for critique see Sheppard 2001), for which it currently stands in university curricula.

As the association with quantitative geography has linked GIS to positivism and conservative politics, it is not surprising that the early exchanges between GIS and critical geographers were polemical and even hostile (Pickles et al. 1995; Wright et al. 1997; Pickles 1997; Schuurman 1999; Schuurman and Pratt 2002). The book *Ground Truth* (Pickles at al., 1995) and related publications unveiled GIS that serves corporate and state interests; facilitates surveillance and control; masks social and economic inequality, deepens the digital divide, and is undemocratic due to its high cost, limited access, and need for expert knowledge; supports the pretence of value-free objectivity, has a masculinist bias and so on (Sheppard 1993; Pickles 1995b, 1997; Goss 1995; Curry 1997; Schuurman 2002; Kwan 2002c). Defenders of GIS accused its critics of ignorance, science hating, and many other sins (Openshaw 1998; Flowerdew 1998). On both sides, debates echoed those between quantitative and qualitative geographers and had an essentializing effect on GIS. It emerged as a quantitative, technocratic, undemocratic, and yet seductive technology linked to science, power, and capital.

HONESTLY, HOW QUANTITATIVE IS GIS?

As critical geographers have begun using GIS technologies, GIS researchers have reflected on critiques, and a new generation of scholars received training in both social theory and GIS, greater reciprocal knowledge and "care of the subject" (Schuurman and Pratt 2002) have resulted in growing examination of GIS potential for non-positivist modes of analysis, including qualitative research (see introduction). This new and very important research, however, either attempts to fit GIS into epistemologies with which it is supposedly incompatible or, alternatively, calls to actually modify GIS (Schroeder 1997; Sieber 2004).

Contrary to that, my purpose is counter the dominant representations of GIS as homogeneous and quantitative (also see Wing and St. Martin 2005 for “heterodox” GIS) and show that GIS and qualitative research have had a potential for joining since the early days of GIS. As these representations close up the possibilities for using GIS in non-positivist contexts, my goal is to create openings for such possibilities building on examination of quantitative and qualitative methods as a continuum. Similar to other research methods, GIS is neither strictly quantitative nor qualitative but may be meaningfully used in different types of research. My approach is inspired by Trevor Barnes' work on quantitative geography (1996, 1998, 2000a, 2001a, 2003) and Gibson-Graham's approach to re-envisioning singular categories (2000).

Opening 1. Non-quantitative roots of GIS

Quantitative analysis is important part of GIS identity but GIS combines diverse conceptual frameworks that reflect its multiple roots (Flowerdew 1998; Clarke 1999). These roots include geography (mapping and spatial analysis), computer science (automation and computing), landuse planning and census administration (handling and display of large databases), remote sensing (image processing and landcover analysis), and geodesy and the military (spatial accuracy and georeferencing). In other words, much of GIS functionality has evolved from fields other than mathematics and statistics. Using GIS requires a certain amount of specialized knowledge but this knowledge is different from the expertise in quantitative analysis.

Opening 2. Computerization vs. quantification

Since its early days the computer technology represented science. The beginnings of quantitative geography in the 1950s coincided with and were facilitated by the introduction of computers, and, as an emerging science, it benefited from this association (Barnes 2000a, 2001a). Computers created an illusion of accuracy in data and calculation, were able to handle large amounts of information, and, just like scientific data, digital datasets had to be systematically organized - all being important for constructing scientific evidence. GIS fits well with all this because it handles large and structured databases and offers specific analytical tools.

And yet modern computing provides a basis for a whole range of activities, whether related to research or not. Researchers alone rely on diverse software packages, many of which automate either non-analytical tasks (e.g., word processing or bibliographic software) or non-quantitative analysis (e.g., graphic display or textual analysis using Atlas/ti). Most of GIS' diverse functionality, too, deals with data visualization and querying, database development, georeferencing, basic distance calculations, topological relationships, and other functions that are not quantitatively sophisticated. Remote sensing software is far more quantitative in this sense because its basic image classification functions rely on complex statistical procedures (e.g., cluster analysis, maximum likelihood classification, principle component analysis, etc.).

Programming has also become a skill linked to science, modeling, and quantification. Early GIS programmers indeed were academics trained in spatial analysis and wanting to implement it in the software (Schuurman 1999). But creating any computer application (including media players, computer games, or word processing) requires programming skills and these skills are different from those required for statistical and spatial analysis. With rare exceptions (e.g., Idrisi), the development of the widely used GIS software is no longer in hands of academics but corporations. The expertise in quantitative analysis is diverged from that of programming.

Finally, most computerized techniques were developed prior to their transfer into the software and thus predate computerization. Overall, computerization variously assists research but being a computer-based technology does not make GIS a default tool for quantitative analysis.

Opening 3. Spatial analysis and GIS

Surprisingly, only relatively few GIS techniques involve quantitative spatial analysis (Openshaw 1998; Flowerdew 1998; Schuurman 1999), which, some GIS researchers and developers claim, should be its core (Clarke 1999; Heywood et al. 2002; Eastman 2003). Keith Clarke who authored a popular GIS textbook admits that in fact and (1999, p.181): "Unfortunately, most GIS packages have contained only rudimentary tools for spatial analysis." Most GIS users, therefore, have access to only basic techniques such as overlay, linear distance calculations, buffering, determining neighbors, etc. that do not involve advanced mathematics. Often these spatial techniques are used (usually with great insight), for instance, to summarize data within new geographic boundaries. Examples include calculating employment opportunities within a certain distance of women's homes (Hanson et al. 1997), mapping banks engaged in predatory lending in relation to census data thus revealing their target populations (Graves 2003), and mapping hazardous accident sites by census units to calculate exposed populations (Margai 2001).

Furthermore, much GIS research deals with methodological issues such as the ecological fallacy and modifiable areal unit problem (Openshaw and Taylor 1979; Wong 2003), appropriate spatial resolution and locational accuracy (Scott et al. 1997), methods for distance calculations (Wang 2000), representation of objects as either continuous or discrete and so on. Some of these problems are GIS specific such as representation in a particular data model or ontologies while others are common to geographic analysis in general. Matters of conceptualization, they are not in themselves quantitative tasks.

In truth, most spatial techniques available in GIS are only marginally "quantitative" despite being very illuminating. Using simple math (e.g. distance measurements or calculations between raster layers), they require spatial imagination skills (e.g. buffering or overlay) and logical thinking (e.g., combining layers in site selection or multi-criteria evaluation). As such, these core functions replicate human spatial thinking about places and phenomena that is common to all geographic research.

Overall, spatial analysis in GIS today is largely qualitative, visual, and intuitive despite its insistent labeling as a quantitative method. Even some recently popular in GIS research analytical methods in a sense further enhance its qualitative aspects. For example, fuzzy sets theory, artificial intelligence, and Baysean probability (Openshaw 1998; Sheppard 2001) - all attempt to replicate human reasoning that deals with multiplicity of connections, blurred categories, and partial knowledge.

Ironically, and also the case with buffering and other basic spatial calculations, the challenge is not in the conceptual sophistication of a technique itself but in how to design and program the appropriate algorithms. Complex programming often produces results that are non-quantitative (cf. word processing software or a recent break-through in laptop industry - "writing" and "drawing" on the screen by hand!).

Finally, many GIS-specific drawbacks including rigid cartographic symbolization, poor representation of people as opposed to geographic objects and the static nature of GIS data and models (Openshaw 1998; Dorling 1998; Poon 2004) pose problems to quantitative and qualitative researchers alike. Using even the most basic GIS techniques assumes a meaningful interface that has been long missing (until recently) from most GIS packages, thus obscuring their conceptual simplicity.

Opening 4. Digital data representation

Digital data representation, so important in GIS, also has, upon closer examination, little "quantitative" content. Digital GIS data (locational and attribute) is commonly equated with large numerical databases suitable for quantitative analysis. But all information designed for computer use must be represented digitally and, therefore, appropriately coded, disregarding whether the data is quantitative or qualitative and whether it is to be analyzed quantitatively or not. Counting (and coding) already implies categorization and fixity (Lawson 1995; Doel 2001) but using numbers to express qualitative properties of geographic objects does not yet amount to quantitative analysis (for example, raster data models only handle numerical attribute data while vector and object-oriented models allow for its alphanumeric representation). Being the heart of GIS (vector) models, topology, too represents very structured but non-quantitative spatial relationships. Finally, one of the main functions of digital data models is to enable visualization, a fundamentally qualitative analytical process (see Opening 5).

In short, digital representation organizes data and thereby imposes structured ontology (Dixon and Jones III 1996; Jones III and Dixon 1998) but is short to stand for quantitative analysis. In word processors, too, letters are digital - and not because they are to be analyzed quantitatively but because they cannot be stored and visualized in the computer otherwise.

Opening 5. Visualization of data

Visualization in GIS is arguably its most powerful and widely used function. Like other tools for graphic data display, GIS makes spatial information immediately accessible to our minds. We must "see" the data whether it is quantitative or qualitative in order to assess its quality, suitability, or completeness. We must display the outcomes of each transformation in order to decide whether it is correct or incorrect. In quantitative research, mapping value distributions helps identify model mis-specification problems (Fotheringham 1997). Yet, visual examination is hardly a quantitative although an important analytical tool for understanding the data. Visualization is so powerful a technique that often the manipulation of data within GIS does not go beyond querying the data and displaying the results (see Opening 6).

Even more importantly, the capacity of GIS to visualize spatial data is the source of its seductive rhetoric, in which the power of maps is combined with that of the information technologies. Maps communicate spatial data in a particularly synergic way and have long been a controversial tool for control over and empowerment of people and places they selectively and specifically represent. While a research tool, maps are embedded within power relations and mediate those relations through spatial representations (Harley 1992; St. Martin 1995; Sparke 1998; Edney 1997; Lewis 1998). GIS further amplifies this power through its validation as a scientific technology (Lake 1993; Sheppard 1993) and by providing unsurpassed computer-based versatility in mapping backed by the faith in computerized facts. GIS does not innocently display spatial data but unveils the worlds to researchers, policy-makers, and the public, the worlds made true through their visualization enabled only now and through GIS.

Not surprisingly, display functions have been an early focus of the GIS industry. GIS software packages with versatile display functionality have come to dominate the market despite their limited analytical capabilities and bias toward one spatial (vector) data model. From their side, GIS academics have contributed a vast amount of research on many aspects of visualization, including technical, computer-related, methodological, cognitive, and social theoretical issues.

As the power of visual impact of GIS is itself dependent upon emotions and other irrational sentiments (Kwan 2002a) that also run counter to the dry logic of quantification, visualization remains the most telling example of non-quantitative functionality in GIS.

Opening 6. Database management and querying

Suggesting its intimacy with the empirical scientific tradition, GIS has been designed to handle large datasets (Flowerdew 1998) such as land parcel, TRI, or census data. Compared to non-spatial database management systems, it organizes data in a unique way - by geographic objects. Assembling and structuring spatial "facts" in a geographic database enables a versatile querying and display of large quantities of data as well as merging information from different sources. The ability of GIS to manage and query data, however, is conflated with the ability to quantitatively analyze it.

Data base development and maintenance, for example, tasks that consume enormous time as GIS textbooks sincerely acknowledge (Clarke 1999), do not involve quantitative analysis at all. Digitizing and cleaning spatial layers (e.g., snapping nodes, building polygons or georeferencing satellite data, etc.) as well as entering, organizing, and verifying attribute data do require specific knowledge of geodesy, geometry, and data structures but not of the advanced spatial analysis and modeling. Building a spatial database for a qualitative research project would require the same technical skills.

Digital attribute data itself often is, even in large GIS datasets, of qualitative nature and includes names (e.g., of owners of land parcels, businesses, or street addresses) or types (e.g., of roads, settlements, soils, or polluting facilities). Not generally suitable for quantitative analysis such data can, however, be queried and logically manipulated using SQL (structured query language). Querying reveals geographic features with a particular combination of attributes or locational characteristics. But even complex attribute and spatial queries require logical thinking and spatial imagination rather than statistical or mathematical skills. SQL enables, of course, manipulation of numeric attributes, but advanced mathematical and statistical calculations are less common and, as will be shown below, are most often performed outside the GIS environment. Thus, the most fundamental and widely used GIS functionality such as visualization, database development, management, and querying are not at all quantitative.

Opening 7. Mathematical modeling and statistics in GIS

Even more revealing of the non-quantitative side of GIS is that both GIS and non-GIS academics who work with the advanced statistics and modeling do not use GIS for this purpose at all. GIS researchers, for example, often use specific algorithms that in commercial GIS packages are either absent or their details are concealed making control over analysis insufficient. These researchers program their own GIS routines by combining the available functions or developing their own dedicated algorithms and use the existing GIS software for display (personal communications; Kwan 1999a,b).

Physical and human quantitative geographers who do modeling and statistical analysis but work outside the GIS field, on their part, use GIS even less. In methodological and epistemological debates in quantitative geography, they only marginally refer to and clearly distance themselves from GIS (Fotherringham 1997; Poon 2004). Many quantitative geographers simply received their training prior to the advent of GIS while others do not find within its environments the capabilities that their work requires (personal communication; Flowerdew 1998; Openshaw 1998). In either case, they do most modeling and statistical analysis using non-GIS software (e.g., MatLab or

IDL), existing narrowly specialized models (such as atmospheric circulation or plume dispersion models), or write programs themselves. Interestingly, this is true even for studies that explicitly focus on spatial processes (for example, Margai 2001; Poon 2004; personal communication).

GIS quantitative capacity is also limited because many statistical techniques including regression analysis simply cannot be applied to spatial data (Getis and Ord 1996). For example, proximity affects spatial distributions and results in autocorrelation problem that violates basic assumptions of conventional statistics. These statistics were developed for non-spatial data and imported into geography without proper adjustment (Barnes 1998, 2001a; Flowerdew 1998; Sheppard 2001). They often do not include locational information and, in addition to ignoring spatial autocorrelation, eliminate, sadly, the very difference between GIS and non-spatial statistical packages.

Another problem is that available statistical techniques, including even spatial statistics, often calculate indices or parameters (autocorrelation coefficients or regression equations) that apply to the entire study region. Local variation in their values is ignored that defeats, again, the purpose of geographic analysis and leads to mis-specified or illfit models (Fotheringham 1997). In addition, the available methods are not equipped to model dynamic processes, incorporate individual-level data, and represent interactions across geographic scales and networks (Poon 2004). Only recently, geographers have developed methods that address these and other problems of spatial modeling (Getis and Ord 1996; Fothergham 1997; Barnes 1998; Sheppard 2001; Poon 2004). Geostatistical techniques, however, are mainly available as separate software packages and only in few GIS systems. Mapping analytical results and increasingly their local variations remains the main functionality that quantitative modelers seek and use in GIS (Fotheringham 1997).

To conclude, in spite the dominant representations of GIS technology as a tool for quantitative geographic research, its alternative reading highlights, on the one hand, the unacknowledged potential of GIS for incorporating qualitative information, and, on the other hand, its surprisingly limited use in quantitative geographic analysis. Clearly, GIS technology is not a fixed and singular identity but a method open to reconceptualization and its use within qualitative research can and should be imagined.

SOCIAL THEORY WITH GIS?

As GIS technology has only marginally fulfilled its promise for quantitative analysis, its new promise for qualitative research also remains to be realized. In particular, GIS might uniquely contribute to critical geographical theory by becoming a visual tool for representing spatiality in such explanations.

Theorizing space has been central to human geography. Conventional GIS perpetuates the positivist concept of space as a container of objects with definite extent and precise location within the Cartesian grid. This concept supports the intent of spatial science to decipher spatial laws that produce patterns independently from non-spatial factors. Critical geography, however, no longer sees space as location of phenomena but as relation between them; space is inseparable from social processes and relations (Massey 1985). Currently, GIS is widely used to map spatial patterns and distributions (spatial science approach) and much less experience exists in mapping non-measurable properties of place, human experience, social hierarchies, power relations and theoretical relationships that are of concern to critical geography. The above openings in GIS may be imaginatively expanded with qualitative research that brings GIS outside the positivist epistemologies. Below are just a few examples of the work already done that also suggest future directions. They include visualizing non-quantifiable experiences, bringing spatiality in explanations through spatial representations, and using the ontological power of mapping.

Although they may be hard to imagine, GIS could provide possibilities for mapping properties of people and places beyond measurable attributes. Doing so would take advantage of the powerful graphic rendering of non-quantifiable spatial information and legitimize it as scientific in various contexts. Conventionally, GIS represents static geographic objects (as discrete vector features or raster surfaces) and their attributes rather than people and their behavior (Openshaw 1998; Dorling 1998; Poon 2004). For quantitative geographers, such inseparability from spatial entities creates methodological problems when modeling people's spatial behavior (Poon 2004). To qualitative researchers, it suggests that differentiated human worlds cannot be represented unless linked to tangible spatial objects. While this may be true, in combination with qualitative methods, feminist geographers have already began to model individual and household experience and represent such hard to quantify experiences as emotions or webs of daily economic practices. Expanding space-time geography, Mei-Po Kwan has visualized three-dimensional daily paths of women from different ethnic and socio-economic groups (Kwan 1999a,b, 2002a) and variations in safety of urban space as perceived by Moslem women after 9/11 (Kwan 2002c). My own research on urban transformations in post-socialism (Pavlovskaya 2002; 2004) included mapping multiple economic practices of Moscow households. In these examples, the in-depth interview and diary information represented individual and household experiences (also see Matthews et al. 2001; Jiang 2003; Cieri 2003). Overcoming the current bias of geographic databases towards numerical information, qualitative researchers have creatively worked with unconventional GIS data sources. In addition to narratives, hand drawn maps, graphics, photographs, videos, as well as voices and sounds have been combined with GIS (Dorling 1998; Sheppard 2001; Kwan 2002a). While technically more challenging, bringing such data into GIS is increasingly facilitated by expanding computer media technologies (Kwan 2002a).

In addition to mapping non-quantitative data, even greater challenge is to represent in GIS theoretical relationships and results of qualitative analysis. They may include spatial configurations of networks, relationships, activities, meaning of places and events, flows that link people and places, and so on. Pictures and diagrams often aptly communicate concepts but representing a theoretical argument spatially is rare. By visualizing socio-spatial dynamics beyond the positivist frameworks, GIS may help further incorporate spatiality into critical geographical explanations as well as other social disciplines that use non-geographic modes of analysis and commonly ignore space. That maybe assisted (paradoxically) by the same inherent spatial focus of GIS that requires organizing the information in explicitly spatial ways. In other worlds, spatial relationships are always implied in GIS data structures but their understanding and analysis should not be limited to and by positivist frameworks. Consequently, GIS also provides the means to think spatially through the entire research process. If space, time, and social relationships are inseparable and mutually constitutive, then theorizing with GIS would create new understandings and explanations.

Even more importantly, however, using GIS in these new ways also creates social ontologies that are inclusive of the relationships, processes, and landscapes that do not exist within conventional epistemologies (Pavlovskaya 2002; 2004). Mapping previously unmapped phenomena (daily paths of women based on their diaries, urban experiences of Muslim women, and informal household economies) or theoretical relationships (how multiple or diverse economies combine in daily lives of households) makes these phenomena and relationships visible and, therefore, theoretically and politically significant. "Positioning" them within GIS space indeed performs an ontological function; it creates the landscapes and worlds that embrace these processes. The constitutive significance of GIS for critical geography is particularly appealing because of its powerful visual impact, ability to legitimize the information it displays and the concern of critical geography with social justice and representation of the unprivileged ontologies.

CONCLUSION

In this article, I revisited the quantitative/qualitative division in geography in order to interrogate the image of GIS technology as suitable only for quantitative analysis. The article demonstrated that the promising possibilities of using GIS in qualitative research exist and may provide a basis for critical geographers to theorize with GIS disregarding the current GIS industry dynamics, software design, and its dominant discourse as a tool for quantitative analysis. In many ways GIS has been a technology that used non-quantitative data and modes of analysis. Its application in "true" quantitative geography and spatial analysis has been surprisingly limited. While its quantitative analytical and modeling power is of concern to some GIS theoreticians, most academic and other users take advantage of its other functionality, the functionality that can equally serve quantitative and qualitative researchers.

The challenge is to open up GIS to qualitative research so that complex relationships, non-quantifiable properties, unprivileged ontologies, and fluid human worlds can be represented and better understood. Re-imagining and reconstructing GIS as a flexible tool for creating diverse human geographies would benefit social theorists and critical geographers in the complex task of social theory development.

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