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Cognitive and Linguistic Aspects of Geographic Space: Report on a Workshop

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Preface and Acknowledgements

This is a report on a workshop entitled "Cognitive and Linguistic Aspects of Geographic Space", held in Buffalo, New York, June 1988. The Workshop was organized by David M. Mark and David A. Zubin, with a great deal of assistance from Scott M. Freundschuh. It was supported by a "Conferences in the Disciplines" grant from SUNY at Buffalo, by the Faculty of Social Sciences (SUNY/Buffalo), and by the Graduate Research Initiative in Cognitive and Linguistic Sciences (SUNY/Buffalo). Roula Svorou and Joe Delotto also provided assistance before and during the meeting. David Zubin, Scott Freundschuh, Matt McGranaghan, and Andrew Frank provided comments on earlier drafts of this report. This report is being published as part of Research Initiative #2, "Languages of Spatial Relations", of the National Center for Geographic Information and Analysis, supported by a grant from the National Science Foundation (SES-88-10917); support by NSF is gratefully acknowledged.

INTRODUCTION

Human conceptualization of space and its reflection in language represent a critical element in the research agenda for geographic information systems and spatial analysis. Spatial reference also is an important topic in linguistics, and spatial concepts play a central role in cognitive science. Development of a "general theory of spatial relations" has been identified as a critical research topic for the National Science Foundation's proposed National Center for Geographic Information and Analysis. Thus far, it seems that research in the spatial sciences has been conducted in relative isolation from research in the cognitive and linguistic sciences.

In response to this situation, a 2-day workshop entitled "Cognitive and Linguistic Aspects of Geographic Space" was held in 280 Park Hall on the Amherst campus of the State University of New York at Buffalo. The primary purpose of the proposed meeting is to bring together key researchers from both the cognitive/linguistic and the geographical sciences, in order to advance progress in both areas.

This report attempts to summarize the scientific content of the discussions which went on during the workshop, and makes recommendations for further work in general, and for a future similar meeting to possibly be held at some time in the near future.

THE PRESENTATIONS AND DISCUSSIONS

Saturday Morning

Len Talmy made the first presentation. His talk was based on a hand-out (see Appendix), and generated enthusiastic discussion. Talmy stated, as a general principle, that we must pull back from a concept of an objective reality, and instead look at cognitive models of space.

Some discussion focussed on the model which divides spatial situations into bounded or unbounded spaces, uniplex or multiplex numbers, and discrete or continuous phenomena. Many spatial terms are magnitude- neutral, but discussion uncovered some which are not, or at least for which the magnitude of the meaning varies (eg. "near"). Apparently, not much work has been done in linguistics on how the scale of the meaning is taken from the words and relations.

Another key point which Talmy emphasized is the idea of figure-ground, and the relativistic nature of much language. In expressions such as "A is near B", we are often forced to choose one object as the ground (B) and the other as the figure (A). In many cases, the reversed expression "B is near A" will simply not be a proper sentence of the English language. Larger and/or fixed objects are more likely to be taken as the ground. General discussion emphasized the role situational, pragmatic, and intentional factors in determining the choice of figure and ground in spatial descriptions. Later discussion extended the relevance of these factors to the reference frame problem.

John Pipkin discussed some specific research projects that he is conducting. These projects involve "getting the geography out of narrative", the extraction of spatial and/or space-time information from narrative text; deictic references play an important part in the problem. Pipkin focussed on two examples: one involved reconstruction of time-space events in the London fire from the diary of Samuel Pepys; the other analyzed newspaper reports of conflict over planning decisions in the Albany (New York) area. Pipkin noted that journalistic writing style attempts to supress deictic reference, and thus may be difficult to analyze. Zubin adds that "high" style in journalism goes to extremes to suppress the spatial, temporal, and actor continuity of narrative in general.

In discussions related to planning decisions, Pipkin presented a model which first sets up a 2x2 table: one dimension, labeled "here-there", indicates spatial location, and may be approximated by a metric cut of geographic space; the other, labeled "good-bad", reflects judgements on the value of some planned facility. Then, in rhetoric or narrative, the speaker/writer collapses those two dimensions onto one. Thus, for a garbage dump location, there=good and here=bad.

Pipkin also cited Johnson-Laird in the assertion that a discourse is spatially coherent if and only if it is consistent with some particular mental map. This raises questions about the nature of "mental maps" and our ability to evaluate consistency.

Saturday Afternoon

Stuart Shapiro presented some material on spatial knowledge representation, based on work by James Geller, one of his former graduate students.

Issues for spatial representation:

- axes for coordinate systems: How many axes? Cartesian or polar?
- names for axes: x, y, x; r, theta, phi; north, south, east, west; front, back, left, right; width, length, depth; etc.
- units for axes: absolute coordinates come with the coordinate system, and are independent of any objects embedded in the space; relative coordinates depend on the presence of objects. Shapiro suggested that "at", "near", and "far" could be viewed as three positions on a 1-D (r) polar coordinate system, that "high" and "low" are two positions on a 1-D cartesian z, etc.
- mappings.
- kinds of parts: real parts such as states within a country (interior details); sub-assemblies such as a peninsula along a coast (sections of object); and clusters, envelopes, such as regions of a country.

Bruce Palmer discussed the use of general linguistic methods in the examination of human understanding of maps and other graphs (as distinct from pictures of real things). He concentrated on 'business graphics', as these are more standardized and simpler than maps, although the same principles may apply to maps as well. Palmer presented a typology of "objective" kinds of spatial relations that occur in maps and diagrams. He expressed interest in designing intelligent multimedia interfaces for geographic information systems (GIS); such interfaces should be task or task-by-person specific.

Discussion suggested that Palmer may be starting with an intuitively available set of spatial relations, and that there would be two important ways to go forward from this base:

1) systematize and objectify the relations to produce an abstract geometry of spatial relations among objects (this is Palmer's move); or

2) seek out other intuitive spatial relations from a cross-linguistic and/or cross-cultural sample to broaden the base of material from which the abstract geometry is to be developed.

In addition to enriching the geometry, this latter move would help to insure that the resulting geometry is not language/culture biased (or that biases are explicit). An example: some languages emphasize in their grammar the notion of "orifice", or opening to an interior space, as a primitive concept. This spatial relation is missing from Palmer's typology.

Next, the discussion moved on to the problems posed by terms such as "near" and "far" which have no precise definitions. It was suggested that such terms may be an example of prototype categorization, based perhaps on time and/or effort as well as distance. As an example in some (most?) cities, "near the grocery store" and "near the concert hall" will have different geometric meanings.

> Editor's (DMM) afterthought: there is a wealth of data in economic and social geography on how far people travel, or are willing to travel, for certain types of goods and services, for their journey-to-work, etc. This may be a good source of information on "prototypical" distances. The meaning of "near" might be approximated by some percentile of the probability distribution of actual travel between points of the appropriate two types, in the appropriate context. "Too far" might be some other percentile, roughly equivalent to the "range of a good" in economic geography-

Someone mentioned Smith and Medin, "Categories and Concepts", published in the early 1980's as a relevant literature source.

Roger Downs spoke about cognitive issues related to geographic education for children. He concentrated on the concept of geographic hierarchy, which is essential to an understanding of the relations among cities, counties, states, countries, continents, etc.

Key concepts include embeddedness, the part-whole schema, and the concept of exhaustive partitioning. Downs' central question is: "What (in the area of spatial concepts) can people understand, how do they understand it, and at what ages can they understand it?"

What skills/abilities does a child need in order to be able to understand a geographic hierarchy? According to the Piaget school, this would require spatial abilities at the "stage of concrete operations" which supposedly develops at age 6 to 10. To understand geographic hierarchy, one must: (a) understand inclusion and transitivity; (b) have a geographic terms vocabulary; and (c) have a graphic or linguistic way to express their ability.

Example: "Can the camel be in the camel's cage and in the zoo at the same time?" Children of age six can answer questions of this sort perfectly with the aid of concrete scale models, and do very poorly when the question and answer are in language. Performance using map-like graphics is at an intermediate level. Geographic hierarchy creates a "figure-ground cascade" that influences spatial abilities and spatial language.

Naive models of geographic space influence spatial language and cognition, and can lead to It errors" in mental maps and geographic reasoning. For example, a sample of college freshmen were presented with a synthetic map (without a north arrow), and asked if they could tell which way was north. Some claimed that they could by observing river flow direction (!). They apparently had adopted the "north-is-up" convention so strongly that they thought that, since water flows down hill, rivers must generally flow south.

Downs also stated that Piaget's model, he feels, is no longer a good basis for map-skills education for children, and that such tasks are "domain-specific."

Scott Freundschuh reviewed the relations between two bodies of literature on navigation and way-finding. One body deals with spatial learning by adults in a new and unfamiliar environment; another deals with children's abilities from a developmental perspective.

Terms for Levels of Spatial Knowledge in Four Models

	Trowbridge	Piaget	Kuipers	Thomdyke & Hayes-Roth
low		Topological	Sensorimotor	Procedural
	Dorni-centric			
middle		Projective	Topological	[transition]
	Ego-centric			
high		Euclidean	Metrical	Survey

Trowbridge's model relates to abilities based on education and/or training, Piaget's model is developmental, and the other two refer to stages in knowledge acquisition by adults in a new environment.

Freundschuh presented his own model, which is intended to subsume the published models. Freundschuh proposes four stages, which he termed procedural, topological, metrical, and survey. The difference between the last two is that Freundschuh's metrical level has correct (Euclidean) local geometries, which are not integrated into a global coordinate frame, whereas in survey knowledge, local geometries are integrated into a global coordinate system.

Someone (Downs) asked whether the difference between the first two stages was that spatial inference was common at the topological level, but absent at the procedural; this appears to be a useful point for further reflection and research.

Also, Freundschuh raised the question of whether the regularity (or irregularity) of the environment influences the transition from procedural to survey knowledge that Thorndyke and Hayes-Roth claimed would happen through extensive direct way-finding experience. Freundshuh believes that a regular environment would assist in this transition, and an irregular environment would hinder it, or perhaps make it impossible to acquire survey-level knowledge based only on knowledge acquired during exploration.

Sunday Morning

Andrew Frank made a brief presentation on some problems of geometry. Kant's view was that geometry is "God-given". Euclidean geometry corresponds closely to Newtonian solid-body physics. Frank stated that the modem view in mathematics defines geometry as a group of properties which remain invariant under some group of transformations. Words may express some spatial properties which are invariant under certain transformations. This leads to the idea that properties of spatial language may define a geometry in a formal sense (see "Key Issues for Future Research" section, below). He expressed interest in Talmy's description, which showed 'surprising' parallels to the modern view of geometry.

Talmy stated that closed-class elements of spatial language (largely pronouns) tend to be topological, plastic, whereas open-class elements (largely nouns) tend to have more fixed geometries. He stated that most of the terms used for spatial relations are:

1. magnitude-invariant (the relations apply independently of the sizes of the objects or the absolute distance between them);

2. shape-neutral (the shapes of the individual objects do not influence the language used to describe their relation);

3. position-neutral (the relations hold independently of where the objects are placed, as long as their relative positions are appropriate);

4. material-invariant (the terms do not change if the materials from which the objects are made changes).

Erwin Segal made reference to the idea that common-sense reasoning about space tends to compare magnitudes by ratio, and not by absolute difference. [In relation to this, there was an article some years back in Scientific American on spatial memory of birds, which reported that, when landmarks in the cage are moved, Nutcrackers (a species of bird in the crow family) search for previously-hidden food at locations correct by ratio of distances between landmarks, not distance to nearest landmark.]

Gould mentioned a book "Metric for Human Perception" by Patrick Heelan, a physicist at SUNY at Stoney Brook, published by the University of California Press in the mid 1980s.

Talmy stated that in large-scale space (not all visible from one point), humans are forced to use mental imagery in spatial reasoning. He claimed that mental imagery is more closely related to topological aspects of language.

Gould mentioned properties of a space defined by air-travel time from State College (PA) to each of 500 other cities. The space thus defined is non-metric; many triangular inequalities are violated, and many times are asymmetric. Air travel space is strongly non-Euclidean. Others argued that, whereas geographic space over small regions may be essentially Euclidean, inter-point distances may appear to follow some metric other than Euclidean if travel within it is highly constrained.

We may be forced into an "Engineer's Handbook" approach in which we look up the situation and use the appropriate geometry.

Frank: "Our perception organizes the space."
Zubin: "Our perception ***constitutes*** the space."

Zubin reported on an experiment by Linde and Labov (1975: *Language* 51, 924-939) in which subjects were asked to describe their own apartments. Only 7-8 percent of the subjects gave Euclidean descriptions with the over-all shape, metric dimensions, etc. Most of the rest gave the interviewer an imaginary tour of their apartment.

Helen Couclelis talked briefly about her paper "Space and Spaces" (H. Couclelis & Nathan Gale, Geografiska Annaler, v. 68B, 1986, pp. 1-12). A hierarchy of six concepts of is based on algebraic group theory: pure Euclidean space, physical space, sensorimotor space, perceptual space, cognitive space, and symbolic space. She gave an excellent example of the difference between the first two: Consider two parallel rulers on a desk; now twist one so that they cross at one end; the point of intersection moved from approximately infinity to the desk at a speed much faster than the speed of light; this is not a problem, since the speed of light applies to physical space, but is irrelevant in pure Euclidean space.

Couclelis echoed Frank's comment that the geometry falls out of the invariance. One should define the relations that should, or do, remain invariant, and then figure out which geometry works.

Couclelis stated that it might be futile to talk about geometries of cognitive space, since every individual is different. Frank stated that we must classify those cognitive geometries, Couclelis suspected that this won't work because the classes still won't apply to individual cases.

Gould stated that we use familiarly-structured scenarios until they break down. Rote learning of paths allows us to drive to work without conscious attention. Couclelis said that we still require feed-back from the environment, and presumably could not drive to work blindfolded, even if no other traffic were on the road.

David Zubin presented a "view from language." Euclidean 3-D space has three equal axes (bias-free). However, language divides space into a 1-D vertical sub-space, oriented in the direction of falling objects; a largely- undifferentiated 2-D space perpendicular to this; and an origin at the observer (ego) (Buehler). Coordinates (either cartesian or polar) may be imposed onto the horizontal space, or reference within it may be in terms of visible or unseen (distant or even imaginary) landmarks.

Zubin noted four stages in cross-cultural observations and research: (1) imposition of observer's culture on observational procedures; (2) recognition of different yet primitive culture; (3) recognition that others are "just different"; (4) recognition that "we do it too!". Cross- linguistic analyses reveal similar things about how language structures space.

[Someone] spoke of children's "mistakes" in which some thought that "north" meant "toward the door", and some even thought that "north" literally meant "up!" Such mistakes appear to confirm the arbitrary nature of compass-based direction terms.

Zubin went on to discuss the *Reference Frame Problem*. Deictic reference frames can be observer-based, or geography-based. They can be inherited from the background, or from direction of motion. Inherent reference frames are derived from the geometry of the object involved. Exterior reference frames of buildings are determined from generic rules, such as those based on canonical encounter, or on the entrance. Inside activities, gaze, seating patterns etc. also generate reference frames. For a church or a theatre, the "front" from the outside becomes the "back" once one is inside. Additional words, such as "at the front" or "on the side" are often used to reduce or remove ambiguity in the reference frame problem.

Zubin also presented and discussed an iterative model whereby an individual selects figural objects, ground objects, and reference frames, and then may further subdivide those (Mark, Svorou, and Zubin, Proceedings IGIS'87, in press). The speaker first selects a Figural Object, perhaps in response to a query such as "Where is the last subway stop?". Next, the speaker selects a salient Ground Object with respect to which the position of F will be specified. Then, the speaker selects a major- region of the Ground, which will be its inside, surface, or surround. If this region is sufficiently specific, the speaker can proceed directly to a linguistic coding of this information, using the semantic relation loc(F) = R(G), i.e. "the location of F is a region of G". This would yield a description such as "The last subway stop is near the Aud". However, if the speaker wishes to be more specific about the location of the Figural Object, then the speaker must select a Reference Frame, within which the selected Region is partitioned in sub-regions. Then the speaker picks a sub-region, and assigns it a value within the reference frame, for example, [FRONT] or [INWARD] or [SEAWARD]. The information is now ready for linguistic coding via the mechanisms mentioned above. Reference frames can be inherent in the Ground object, or be related to the positions of the speaker/listener, or be derived from cardinal directions, etc. In English and other languages investigated by [Zubin and co-workers], reference frames tend to be inferred from the linguistic and situational context, and are rarely specified in the utterance. Complex region-designators such as "at the front of' (inherent) or "on the other side of' (deictic) not only specify a Region, but also the reference frame used (Zubin & Choi 1984). Rules for determining valid and best reference frames for geographical situations represents an important research topic.

Peter Gould presented a brief and clear statement about the role of language studies in GIS, and also about the role of GIS in geographic education. By turning to cognitive and linguistic realms, we can make geographic software into use by ordinary people who do not want to have to learn specialized command languages. Bottlenecks are seen in GIS. Are they technical or conceptual? Perhaps both. Cross- linguistic work does not help. If one wants all specimens of a certain type of plant collected near Edinburgh, how many kilometers does "near" mean? If we request from the GIS all AIDS cases between Memphis and Chattanooga, what does "between" mean? How far from the shortest path can a case be and still qualify? Gould contends that we cannot pre-program interpretations of such issues, but must use user-machine interaction. Perhaps such queries are better posed using graphic interaction (via mouse or similar device), rather than through calibration of the quantitative "meaning" of terms in spatial language.

Gould noted the striking contrast between the richness of linguistics and the constrained nature of geographic information systems. Their use may severely constrain the questions that will be asked in the future. He claimed that there has been very little intellectual success in GIS, little creative and illuminating use. Current GISs are adequate for trained resource managers and planners. By training people, such systems can remain adequate, but they may not be good for either academic researchers on the one hand, nor for casual, untrained users on the other. Can GIS be made more useful to these other constituencies? If so, should we try to do it, or leave GIS to trained technical personnel?

Gould's presentation sparked a vigorous and extensive discussion, and several participants disagreed strongly with some of his opinions. It is likely that many of these issues would not have been discussed at all if Gould had not been there to challenge assumptions that were implicit to most participants. After the workshop, Gould wrote an essay developing his ideas, which is attached to this report.

Sunday Afternoon

Grant Head began by reviewing material from his 1984 Cartographica paper "The Map as Natural Language: A Paradigm for Understanding." To illustrate the idea that a map and a text could have similar 'deep structures', Head showed an illustration from that paper. Then, he discussed a workshop on semiotics, graphic languages, and maps, held in Waterloo, February 1988. At that meeting, a 3-level model of the cartographic process was developed. The levels, from lowest to highest, are:

DATABASE LEVEL	"the logic of the legend"; - graphic component (expression); - noetic component (content).	diagram(s) (logical relations)
CARTOGRAPHIC LEVEL	- position on basemap; - cartographic symbols	a drawing (spatial relations)
VISUAL LEVEL	- pattern recognition - symbol recognition	a mental image (perceptible relations)

Geographic data are inserted at the intermediate (cartographic) level. The model appears useful for map design, for teaching map-reading, and in research on cartographic communication.

Head asks: is the difference between observing the real world and map reading analogous to the difference between hearing language and reading it?

Talmy asks if the cartographic process begins with the rich reality and then abstracts out the things of interest.

The question of whether language and vision are hooked up to different parts of the cognitive system was raised. Whatever, the question of which spatial tasks are best done using a visual "interface" and which using language is a critical one.

The following version of Grant Head's presentation was submitted after the conference:

THE PROPOSITION AS THE BASIS OF CARTOGRAPHIC COMMUNICATION

C. Grant Head Wilfrid Laurier University

The perspective that I bring to this meeting is that of a practicing and research cartographer within the discipline of geography. My main concern is the process by which information is transmitted through maps. My focus is upon the interface between conventional hard-copy maps and human users.

In-depth work with the concept of cartographic language is not long- standing. A decade ago when I began my work the main body of theoretical cartographic research had been amassed as a result of about fifteen years of research in psychophysics, largely dealing with individual map symbolism components, today called "graphic or visual variables"; we learned much about map reader perception of circle sizes and grey values, for example. In terms of the overall transmission of map information, however, we used in fact still do use, a model based on sender-medium-receiver and largely concerned with the potential loss of information in the process. (Our use of this paradigm is well illustrated in L. Guelke [ed]: The Nature of Cartographic Communication, Cartographica Monograph 19, but Guelke's own article in the collection points to the changes to come.) Gain of information through cognition was difficult to fit within this theory.

Barbara Bartz Petchenik (1975) explicitly recognized (in print) the importance of cognition. Yet it was still difficult to see cartographic communication as a language problem. Petchenik and Robinson--who had published the deepest exploration of the cartographic process in 1976--maintained "Any attempt to apply to mapping the principles of operational structure out of which arise the grammar of a language is wasted effort" (Robinson and Petchenik, 1976, p. 67). In essence, they appear to have based their position on the ideas that there are no units on the map comparable to words, and that there is no syntax similar to that of natural language. Map symbols should not be considered words, they suggested, because they do not keep fixed meanings map-to-map and because they cannot be isolated with any certainty as units relative to the rest of the map. There has continued to be problems with the idea of relations between map symbols because the position of the symbols is usually fixed by their relative geographic position rather than by any syntactical relations of the information they may be carrying. But all these problems disappear, I would assert, when we use the language analogy more fully and discover that all communications involve both a content and an expression level. Only on the map face itself do we have these problems with the notions of words and syntax. At a content level, in the minds of both sender and receiver, there should be no problem in applying language concepts. And during map reading, the reader selectively extracts and combines to create chunks and then links them using a schema drawn from long-term memory. As Andrew Frank noted in discussions today, "our mind brings geometry to organize the world", and so it also brings structures to a visual display such as text or a map.

I am not sure whether communicating information through maps is like using natural language or whether it is using natural language; I also am not sure whether it matters. In any case, the concepts of human information processing and of the processing of natural language such as the models of Dominic Massaro (1975) fit the map reading process closely. Central to my thinking is a deep propositional structure held by sender and receiver. I have chosen the HAM (Human Associative Memory) model of Anderson and Bower (1973). There are others, even by Anderson and Bower, and there is nothing (except the people to do it) to stop us investigating alternatives. But I suggest that the HAM propositional structure offers much potential.

The basic proposition of the HAM model is built from fact and context components, each in their turn being built from subject and predicate and from space and time. In cartographic or geographic language the subject is the thing whose distribution is being communicated (eg., firewood production), the predicate is the spatial pattern or form of distribution of the subject (eg., a single focus, decaying outward from that focus), and the spatial context is the ties of parts of that distribution to aspects of the non-subject space (often called real geographic space, with place-names, capes and bays, etc.).

As I have pointed out in my 1984 paper, the acceptance of the paradigm of cartographic communication as natural language communication has several implications for cartography. First, if map makers recognize the basic propositional components, they can design their maps so that the map, the expression of these components, makes it easier for the map reader to chunk the most relevant aspects of the map graphics; at the least the map makers could avoid working against the readers. Secondly, if, as I maintain, the majority of the population has little idea how to read a map, much could be done through the school system in the teaching of basic map reading skills (not just how to measure scale or what brown means as a hysometric tint) in a manner closely akin to the teaching of a second language; the literature in language teaching is huge. Thirdly, even if we were merely to replicate studies done in human information processing and in psychological linguistics, experimental research in the functioning of the cartographic language could keep us all excited for years.

This is the first time that I have had the opportunity to expose these ideas directly to linguists, cognitive psychologists and cognitive scientists. Do they make sense? If they do, then we need to elaborate them. The reference frame model presented by Zubin and Mark seems to relate closely to spatial context as it appears in the propositional model, and the form characterization (could we read "prototype") concerns of McGranaghan appear to be applicable to aspects of the proposition's predicate. The spatial relation primitives presented by Talmy and by Palmer appear to offer considerable promise in defining essential aspects of both predicate and context. And is there a possible marriage between the logical framework formalism for knowledge representation and the propositional model?

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Matt McGranaghan addressed the relative roles of language and imagery in thinking about geographic distributions. To illustrate the problem he showed a series of slides representing elevation surfaces and asked participants to compare the surfaces. McGranaghan argued that solution of the task, even when both surfaces are present in the visual field, requires breaking down the surfaces into features and coding them, and reasoning on them propositionally. McGranaghan tended to equate "propositionally" with "linguistically;" linguistic coding would almost certainly help in a memory test, but its role in a perceptual task (comparing two stimuli both present) is unclear.

Later, on June 29 1988, McGranaghan submitted the following short paper on the topics he addressed in his presentation:

ARE MENTAL MANIPULATIONS OF SURFACES DONE IN LANGUAGE OR IMAGE SPACE?

Matthew McGranaghan, University of Hawaii

The interplay between language and imagery for thinking about spatial relations is very complex. Neither words nor pictures seem entirely adequate without the other. Language seems to capture binary relationships between features (beside, in front of, near) while images are required to deal with more complex configurations.

In general, we lack terms which specify the spatial structure of assemblages of peaks, saddles, spurs, ridges, and draws, but in some cases we do identify prototypical configurations, such as an atoll, a dissected volcanic cone, or a drumlin field. Each of these admits of many variants in spatial structure, but conveys distinguishable surface configurations (perhaps through components and not arrangement).

Using these labels to specify the spatial configurations eliminates, for some tasks, the need to: 1) resort to mathematical formalisms, such as Cartesian coordinates, 2) go to heroic extremes with combinations of "next to", "behind", "after", "across" and "along" to relate the features, or 3) draw a map illustrating the pattern. Such cases assume the prototypical configuration is known to both speaker and listener. Peterson (1981) showed the importance of prototypes in mental processing of spatial arrangements of map symbols.

Consider comparing surfaces to establish whether they are identical. One could encode each surface as its prototype by attaching a label and then compare these labels, or one might compare (sequentially) the (binary) relations found among the features in each configuration, or one might compare whole images at once.

The first alternative would be relatively quick at rejecting the identity of surfaces with different prototypes but might falsely affirm the identity of different surfaces with the same prototype.

Rejecting the identity of different surfaces from the same prototype would seem to require one of the other two strategies. Comparing binary or low n-ary relations one after another would affirm identity only after exhaustive search of the relations but could reject identity upon noticing one discrepency, resulting in slow affirmation and relatively faster rejection of identity. The global, wholistic, or parallel comparison should require the same time to affirm or deny identity.

Simple experimentation should establish which of these situations obtains. In informal testing, the peaks seem to be the features people notice. To compare very similar images people compare the relative locations of the peaks in each.

Certainly the "behind" and "to the left of", as labels, must also have prototype effects. Relations coded with these terms are likely to be remembered and processed as if they were more like the prototype than they are. One test of a spatial language would be to note how far a feature can be displaced before the relocation is detected in the language.

There are several implications for user interfaces in GIS. If people characterize distributions (patterns) in words they would tend to be highly generalized. Mental overlay of these representations would be very error prone (owing to the degree of generalization) but fast. Most typically however, a good prototypical category would not be available.

Without the prototype, comparing (adding, taking ratios, etc) two surfaces involves constructing a set of new features from corresponding locations on the original images to produce a new image. If this is done in imagery we are saved much grief. If it is done propositionally then the code for corresponding areas (which may or may not coincide with features) would be used to produce the code for the area on the new image.

When distributions can not be encoded verbally, any comparison or joint manipulation of surfaces will quickly become a very large task. The limits on mental imagery suggested by Kosslyn (1983) cause one to suspect that the task requires both input images to be present for the user and probably should be done by the GIS and only the results presented.

This discussion has avoided questions of how the scale of a prototypical surface affects using it for tasks and how two prototypes would be aligned to allow them to be used to produce a third surface. Is the reference frame in these surface images based on a center, or central feature or on the boundaries of the block diagram? Do people center the cone and the atoll on some feature-determined point or if one were off center would the summation result in an asymmetrical surface?

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Roula Svorou discussed the origins of open-class spatial terms. She stated that, historically, closed class elements of a language are derived from open-class elements. Body parts and geographic setting are a very important source for spatial terms.

Svorou discussed cardinal directions. Not all languages use them, but many do. In the Indo-european languages, there is a single etymology for the cardinal directions that is reasonably transparent; this suggests that the terms are relatively recent. Words for North and South predominantly derive from celestial events or from atmospheric events.

Some of the spatial terms discussed by Svorou are included in the Appeneces to this report.

Len Guelke reviewed recent paradigms for geography. He suggested defining a particular set of problems of concern. The focus on landscape and "man-land relations" was an early theme of great importance. Environmental determinism was in this tradition, and when that was rejected (in part because of racist implications), so was concern with landscape. In the spatial analysis paradigm from about 1950 on, landscape studies and regional studies were unpopular. However, concern with cognitive structure, and the connection of that to the structure of humans' physical environment, may lead to a return to a concern with landscape.

David Mark summarized the over-all problems to be addressed. He showed diagrams of radial reference frames, and noted the risk of incorrect translation of spatial terms between languages if the informants and the interviewers are assuming different reference-frame geometries.

Mark also presented three spatial interpretations of the region represented by the phrase "North of the Airport". The most narrow view would include in the region only those points for which a line drawn due south of the point would hit the airport. The broadest view would draw an east-west line through the airport, and consider all points north of that line to constitute the region. Realistically, the phrase might often refer to a segment approximately 45 degrees either side of a line due north of the airport, with fuzzy boundaries and an outer boundary.

KEY ISSUES FOR FUTURE RESEARCH

Geometries of Spatial Language

Andrew Frank defined a geometry as properties which are invariant under a group of transformations. We can treat spatial language as the property of interest; invariance can be defined in terms of validity or in terms of meaning. This is a key research question:

"Which spatial terms and constructions are invariant under which transformations?"

A weak version of invariance of spatial language would examine whether the phrase or sentence is a valid part of the language (i.e., "makes sense") after the transformation. A stronger version would look for transformations under which the meaning of the linguistic expression remained unchanged.

Reference Frames on Maps

Are reference frames used at all in map-reading and in describing spatial relations on/from maps and in describing spatial relations from maps? If so, what are the similarities and differences between real- world and map-based reference frames? Does vertical presentation of the map (on a wall or on a CRT) make a difference to reference frames used to produce the spatial language, or does the lettering orientation produce the same effect as verticality anyway?

Scale and the Reference Frame

The reference frame in the neighborhood of an object or object-pair has a size as well as a shape and parts. "North of' and "in front of" only are meaningful within some limited range of distance from the reference or ground object. How do the speaker and the listener manage to assign similar scales and extents to the reference frames? The idea of prototypes and the explicit or assumed form of interaction between the objects may be critical. The expression "My house is near my office?" probably must be interpreted in terms of prototypical journey-to-work distances in the region and culture in question; the expression may mean that the distance is not in the upper part of the prototypical range. A related concern asks how the scale of the reference frame relates to the problem of geometries (invariant properties) of spatial language?

A Fundamental Problem with Mental Maps Research

When subjects are asked to draw out a subset of their "mental map" on paper or a blackboard, there is a serious problem because the spaces on which the drawings are made are 2-D cartesian (Euclidean) spaces. If the subject's mental model is not Euclidean, then the maps must be "distorted" as it is drawn. If it is drawn with pencil on paper, part way through the subject may notice that conflicts or contradictions are about to happen, and begin to "rubber-sheet" the drawing to make things meet. Is there a computer-based way to avoid this? (Perhaps only let them see a small window, and allow for "overlap" based on the route used to reach the current location.)

Language and GIS

Do we need linguistic input for GISs at all, or can all GIS queries be formed more effectively with a Macintosh-like, graphic, icon-based interface? It seems that complex queries, such as "find all Burger-Biggie restaurants within 250 meters of fire halls" are very difficult to pose using menus or icons, and rather easy to pose using language. How common are such examples?

Appendix A: List of Participants

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How Language Structures Space

Leonard Talmy
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I. introduction

language has fundamental parameters & categories that
  structure the conceptualization of space

similar & dissimilar to conceptual structuring systems
  in other cognitive domains, e.g., visual perception, reasoning

three principal "imaging systems" in language for structuring space:
  schematic structure
  viewpoint
  distribution of attention
 +
  change in these through time

principal structuring done by
  closed-class (grammatical) elements
    e.g., prepositions, demonstratives, inflections
majority of content contributed by
  open-class (lexical) elements
    i.e., nouns, verbs, and adjectives

space-structuring features can be:
  universal --the same across all languages
  language-particular --specific to particular languages
    which can form a typology

direction of fit between cognitive maps and physical space:
  predominant: conceptual structure imposed by language on space
  secondary: "objective" characteristics of space

II. schematic structure

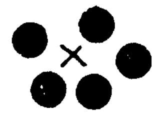
A. basic examples of schemas for spatial structuring in language

1. <u>by prepositions</u>
--location --the Reference Object is treated as...

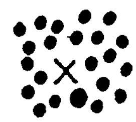
a. *near* ...a single point
  The bike stood near the boulder.

b. *between* ...a point-pair
The bike stood between the boulders (i.e., two of them).

c. *among* ..a set of several or more points
The bike stood among the boulders.

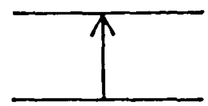


d. *amidst* ...a set of points numerous and close enough to constitute an aggregate
The bike stood amidst the jungle vines.



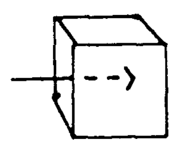
--motion

e. *across* ...a plane bounded at opposite sides
The bike sped across the field.



f. *through* ...a planar / circular / cylindrical form
The bike sped through the plate glass / doorway / tunnel.

g. *into* ...a plane so curved as to define a volume of space:
The bike sped into the garage.

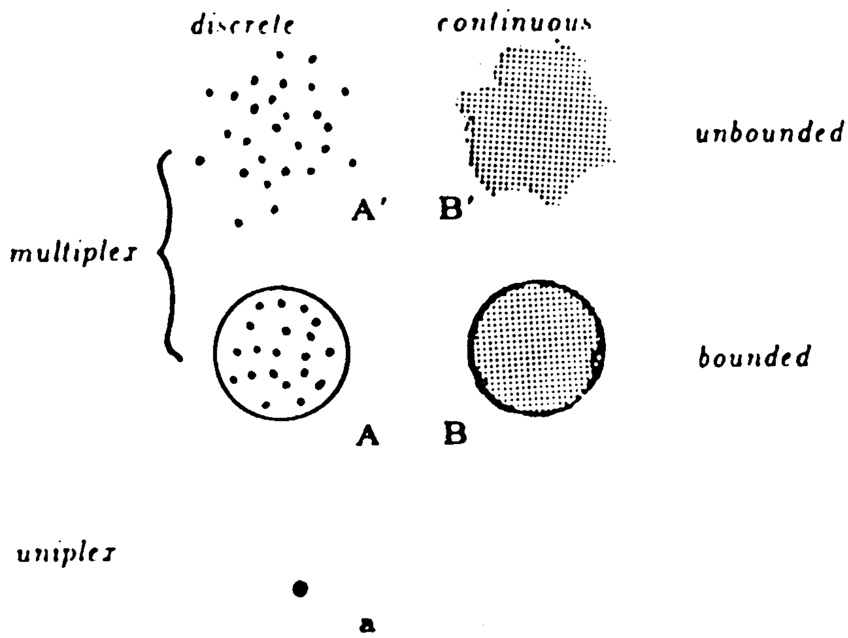


2. by demonstratives

this/that: 'on the speaker-side / non-speaker-side
of a conceptual partition drawn through space
This chair is broken. / That chair is broken.

by nouns

principal parameters:
state of boundedness: bounded / unbounded
plexity: uniplex / multiplex
state of divideness: discrete / continuous



A′: timber
A: a forest
a: a tree

B′: water
B: a sea

test for state of boundedness:
We flew over a sea in 1 hr.
*We flew over water in 1 hr.
We flew over some water / a body of water in 1 hr.

can interact with grammatical elements
triggering certain cognitive operations:

some: bounding
water (unbounded continuous) --> some water (bounded continuous)
-ery: debounding
shrub (uniplex) --> shrubbery (unbounded continuous)
-s: multiplexing
tree (uniplex) --> trees (unbounded multiplex)

B. topological character of spatial structuring in language

1. magnitude-neutral (distance or size):

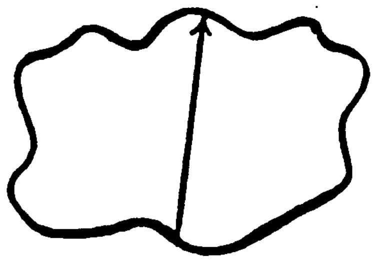
a. The ant crawled across my palm.
The bus drove across the country.

b. This speck is smaller than that speck.
This planet is smaller than that planet.

2. shape-neutral

a. The train zig-zagged / circled through the woods.

b. The ship sailed across the sea.



3. linguistic vs mathematical topology

in: a plane so curved as to define a volume of space

like math:	magnitude-neutral:	in the thimble / volcano
	shape-neutral:	in the well / trench
unlike math:	closure-neutral:	in the bowl / ball
	continuity-neutral:	in the bell-jar / birdcage

C. homology of temporal structuring to spatial structuring in language

Space	Time
a. A bird sat along the ledge.	I sneezed (once) during the performance.

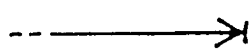
a point located on a bounded linear extent

b. Birds sat all along the ledge. I sneezed all during the performance.

points distributed over a bounded linear extent

c. This road goes as far as Chicago. He slept until she arrived.

a directed linear extent bounded by a point at its further end



d. This road extends for 3 miles. The performance lasted for 3 hours.

a bounded linear extent measured for length

III. viewpoint

A. in space

1. a. steady-state long-range viewpoint with global scope of attention
   b. moving close-range viewpoint with local scope of attention

2. a. There are a number of houses in the valley.
   b. There is a house every now and then through the valley.

3. a. The wells' depths form a gradient
   that correlates with their locations on the road.
   b. The wells get deeper the further down the road they are.

B. in time

retrospective-- viewpoint at later event
After I left Beograd, I arrived at Sofia.

prospective-- viewpoint at earlier event
I left Beograd before arriving at Sofia.

conspective-- viewpoint moves through time apace with the events
I left Beograd and then arrived at Sofia.

prospective with uncertain relative future
I left Beograd for Sofia. / ...to go to Sofia.

prospective with speaker's retrospection
At the punchbowl, he was about to meet his first wife-to-be.

IV. distribution of attention

A. primary vs secondary attention

ascription of *Figure* vs *Ground* status to elements within a scene

The bike is near the house. ≠ The house is near the bike.

1. *Figure*: a moving or conceptually movable object whose site, path, or orientation is conceived as a variable, the particular value of which is salient issue

   Ground: a reference object (within a reference frame) with respect to which the Figure's site, path, or orientation is characterized

B. scope of attention

motion example: car driving in terrain

1. global frame --speaker's viewpoint outside car + terrain:
   terrain seen as stationary; car as moving relative to this

   I rode along in the car
   and looked at the scenery we were passing through.

2. local frame, including just car + terrain
   speaker's viewpoint at car (viewpoint-identifiable object):
   car seen as stationary; terrain as moving relative to this

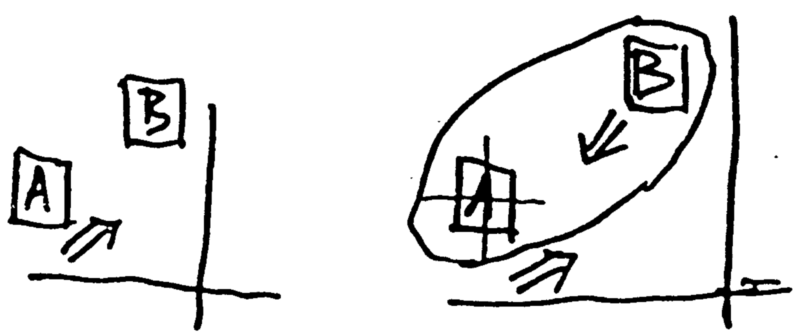
   I sat in the car and watched the scenery rush past us.

3. change in scope of attention through time--
   switching between global and local framing in mid reference

   I was walking through the woods and this branch hit me.
   As I rode along on my horse, the air rushed past my ears.

4. constraints on where viewpoint can be placed within local framing

   *We and the scenery rushed past each other.



C. focus of attention changing through time

1. virtual motion of reference object

linguistic / conceptual relations between:
a) moving object(s) / mass coming to occupy locations previously unoccupied
b) stationary object(s) / mass statically occupying all those locations:
moving local attention reaching locations in same pattern as for (a)
c) stationary object(s) / mass statically occupying all those locations:
static global attention encompassing the whole

--linear extent

distinct spatial expression for (c) type
a) The train goes from one town to the other.
b) The track goes / runs / extends from one town to the other.
c) *The track lies from one town to the other.
The track lies between one town and the other / between the two towns.

same spatial expression for all three functions:
a) The car drove around the entire city (in 10 minutes).
b) The wall goes / runs / extends around the entire city.
c) The wall stands around the entire city.

--areal coverage

a) The oil spread out in all directions over the water from where it spilled.
b) The fields spread out in all directions over the land from where I stood.
c) The fields covered / lay over all the land where I stood.

--alternative directions of attentional scanning

b) The road widens toward the east.
b') The road narrows toward the west.

--shifting-attention mode mimics not just path, but also rate, experience

b) The corridor suddenly drops just beyond the Pharoah's tomb.

2. virtual pathway to encounter with reference object

stationary object's location characterized in terms of
path that one's attention or (a) body or (b) body-part
could follow to encounter it

a. whole-person virtual path

The store is (just)
over the hill.
around the corner.
past the billboard.
down the block (a little ways) (from where we are).

b. body-part virtual path

The vacuum cleaner is down around behind the clothes hamper.

NB: no necessary sequential iconicity
The bathroom is around the corner a little ways down the hall from here.

V. underspecificity --intrinsic property of language

A. alternativity --property of language resulting from underspecificity

primary attention on alternative subsets of aspects within referent scene

1. different aspects of same object called up by the context

	all "box" aspects irrelevant except:
The plate is on the box.	--"box" has a (horizontal) surface
The ball is in the box.	--"box" has an interior space
The doll is 20 ft. away from the box.	--"box" is a localized mass (schematizable as a point object)

2. speaker selects among alternative aspects of same object for expression

--alternative aspects of Path / Reference Object

(a) He walked across the wheatfield. / (b) He walked through the wheatfield.
attention on / schema imposed for:
(a) the field as a horizontal bounded land parcel --wheat on top disregarded
(b) the wheatstalks as a medium --land surface underneath disregarded

(a) We went over the mountains. / (b) We went across the mountains.
attention on / schema imposed for:
(a) mountains as elevated above the land; path rises and falls to clear them
(b) mountain crests as forming kind of "plateau" within which path lies

--alternative aspects of an orientational complex

The bike is--

(a) north of the church. (earth-based reference-frame)
(b) behind the church. (object-based reference-frame)
(c) left of the church. (speaker-based reference-frame)

3. linguistic / cultural "preselection" among alternative schematizations

different constraints within a single language

--on schematization of Reference Object

car schematized as enclosure:
be *in* the car / get *into / out of* the car
bus schematized as platform:
be *on* the bus / get *onto / off of* the bus

different constraints across languages

--on schematization of Reference Object

schematization of 'table':
English: planar tabletop essential geometric element; legs are appurtenances
Atsugewi: tabletop + legs constitute a volume
event: throwing ball between table's legs to someone
English: I threw the ball to him *under* the table.
Atsugewi: I threw the ball to him *through* the table.
--this option not available in English

--on reference-frames within an orientational complex

English: for stationary object, either earth-based or object-based reference-frame
for mobile object, only object-based reference-frame
Wintu: for any object, mainly only earth-based reference-frame

English: The bike is to the left / west of the church.
The bike is to the left / *west of me.
My left / *west arm itches.
Wintu: The bike is west/*left of the church/me.
My west/*left arm itches.

B. cognitive fleshing-out of underspecificity

speaker intends that the additional necessary specifics
will be obvious to / calculable by hearer from context

locative *across* formula: X be across Y from Z

1. regular cognitive fill-ins for omitted "Z":

The bike is across the field.

(a) from the last reference-point in the discourse
e.g., from where I said that the tractor broke down

(b) from the usual / canonic reference-point for that situation
e.g., from the only gas station on the road

(c) from where we are now standing

2. regular cognitive fill-in for omitted "Y":

The bike is across from the gas station.

(a) across the bounded plane obvious from the context
e.g., across the field, the street

C. ambiguity due to unresolvable underspecificity

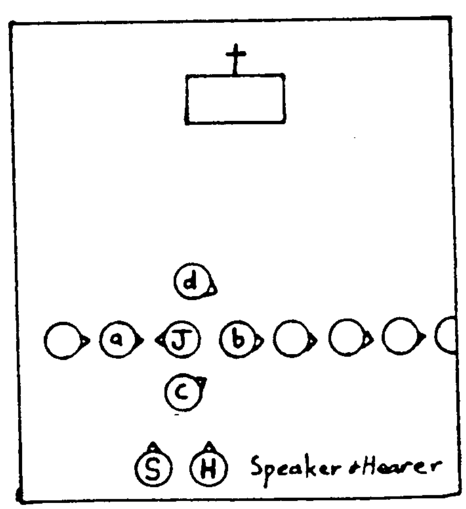
Who is in front of John

(a) that he's facing?

(b) in line?

(c) from where we're standing?

(d) in the church?



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LEXICAL SOURCES OF SPATIAL TERMS

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1. Two models of lexical derivation of spatial terms

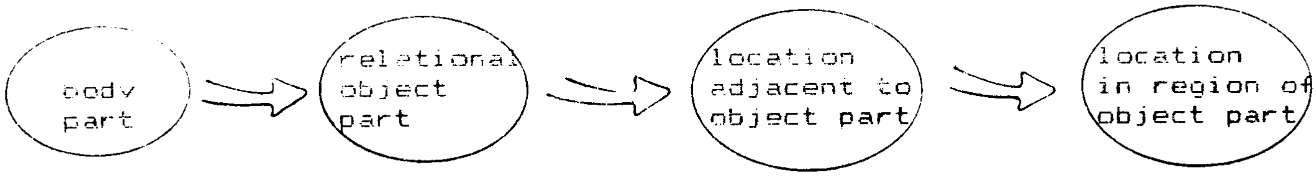
THE ANTHROPOMORPHIC MODEL

Body parts		Spatial grams	Example languages
face, eye, forehead mouth, breast/chest	>	FRONT-REGION	ABKHAZ, BARI, BIHARI, CAR, HALIA, HAKA, ISLAND CARIB, KAROK, MELANESIAN PIDGIN, PAPAGO, TIGRE, !KUNG
back	>	BACK-REGION	BARI, BASQUE, GUAYMI, HAKA, HALIA, ISLAND CARIB
head	>	TOP-REGION	ABKHAZ, CAR, Chalcatongo Mixtec, Ewe, Finnish, TIGRE
buttocks, hips, foot	>	BOTTOM-REGION	BARI, Chalcatongo Mixtec, HALIA, NAVAJO, SHUSWAP
ear, flank, ribs, heart, (abdomen)	>	SIDE-REGION	ABKHAZ, BARI, BASQUE, Korean, PAPAGO, TIGRE
breast/chest, waist	>	MEDIAL-REGION	Margi, Ossetic
heart, stomach,blood	>	INSIDE-REGION	ABKHAZ, !KUNG, PAPAGO, Tubatulabal
forehead, mouth	>	EDGE	Ewe, Margi, PAPAGO, Tarascan

THE PASTORALIST MODEL

Body parts		Spatial grams	Example languages
head	>	FRONT-REGION	NAVAJO, Maasai
buttocks, loins	>	BACK-REGION	PAPAGO, Maasai, SHUSWAP, ISLAND CARIB, Vai
back	>	TOP-REGION	CHACOBO, Chalcatongo Mixtec, SHUSWAP
belly	>	BOTTOM-REGION	Chalcatongo Mixtec

2. Region expansion

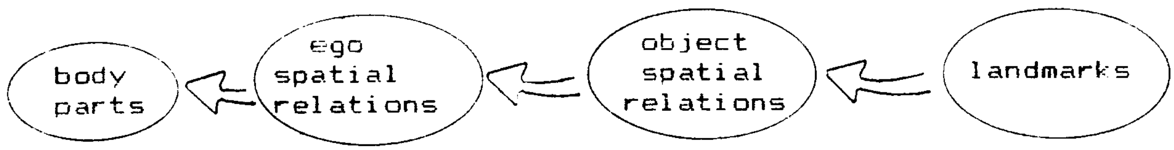


3. Lexical derivation from landmark terms

LANDMARKS

Landmarks	Spatial grams	Example languages
sky/heaven, summit, peak/mountain top/ roof, cape	TOP-REGION	BASQUE, Ewe, HALIA, GUAYMI, NAVAJO
ground, earth, soil root	BOTTOM-REGION	Hausa (50 other African languages:Heine & Noske 1988)
shore/land, house, hole	INSIDE-REGION	ABKHAZ, CAR
field, doorway	OUTSIDE-REGION	ABKHAZ, Armenian, Breton, Gallic, Irish, Lithuanian, Latin, Greek, Persian
field, doorway	FRONT-REGION	Middle Welsh, (1 African language:Heine & Noske 1988)
track, trail, trace footprint	BACK-REGION	ABKHAZ, GUAYMI, ISLAND CARIB, NAVAJO, TIGRE, Middle Welsh
less frequently,		
riverside	SIDE-REGION	BASQUE
further bank	OPPOSITE TO	BIHARI
fish dam	ACROSS	KAROK
shore/land	ALONG	GUAYMI
canyon	MEDIAL-REGION	PAPAGO
road	VIA	ABKHAZ
road	THROUGH	PALANTLA CHINANTEC
road	TOWARDS	Chalcatongo Mixtec

4. Region reduction



5. Large-Scale Environment Orientation terms

GUAYMI	jate	"shore,land, interior, (south)"
	motokucre	"toward the outside or sea, (north)"
	koderi	"in the direction whence the river takes its rise, (east)
	nenden	"(west)"

6. Sources of Cardinal Direction terms (C. Brown, 1983)

CELESTIAL BODIES / EVENTS

EAST < rising sun (58)

WEST < setting sun (59)

SOUTH < midday, daytime, daylight (13)
faraway day (Huitoto Muinane)

NORTH < midnight, sun isn't there, to grow dark, pole star (8)
"roundish object revolves, the Big Dipper"(Navajo)

ATMOSPHERIC FEATURES (winds, weather, temperature, season)

NORTH < north wind (17)
cold weather, cold, to be cold, winter season, storm, to soak in, spring, hot season (11)

SOUTH < south wind (15)
summer, changing weather, to be hot, cool wind (4)

EAST < good weather (1)

WEST < winter (1)

GENERAL DIRECTION TERMS

NORTH	<	up	(13)	NORTH	<	down	(1)
SOUTH	<	down		SOUTH	<	up	
EAST	<	up	(4)	EAST	<	down	(2)
WEST	<	down		WEST	<	up	

EAST (front)

NORTH (left)  SOUTH (right)

WEST (back)

Indo-European
Dyola
Ambyr
Yarebu
Totomac

SOUTH (front)

EAST (left)  WEST (right)

NORTH (back)

Avestan
Old Persian
(Egyptian)

WEST (front)

SOUTH (left)  NORTH (right)

EAST (back)

Hawaian

NORTH (front)

WEST (left)  EAST (right)

SOUTH (back)

Shoshoni
Mataka

ENVIRONMENT-SPECIFIC FEATURES

-- river, stream, straits
-- at the pines
-- desert
-- wilderness
-- rocky place
-- big sierra
-- lagoon
-- place of many cannibals (Zulu)
-- towards Salt Lake (Zuni)
-- Haka EAST < direction of Burma
WEST < direction of Lushais
NORTH < direction of Tashons
SOUTH < direction of Zoes

Geographical Information Systems, Cognitive Science and Linguistics: Reflections on Connections

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Doubting Thomas was not always popular with his companions of greater faith, but he should not be confused with Judas Iscariot. At least Thomas never had his palm crossed with the silver of a research grant. We express doubt in order to lead thinking to a different perspective from which to view something that has been put forward as highly speculative, or has become taken for granted. We traditionally regard doubt as negative, when perhaps, in good dialectical fashion, we should turn it on its head and think somewhat oxymoronically about 'positive doubt'. After all, many major advances in science have come from a sense of unease about the way present thought is moving. It is not a bad thing to keep an awkward 'uneaser' around, even if only as a whetstone to hone your own blade to a keener edge.

We are concerned with the set intersection **Geographical Information Systems** $\cap$ **Cognitive Science** $\cap$ **Linguistics**, the first two representing new fields of endeavor less than a quarter of a century old, the latter an established field a century and a half old in the university, with intellectual roots stretching back to the Academy. We suspect the intersection is not the null set; we wonder what the elements are that form it; and we wish to explore the intersection, and examine as many connective elements as we can. These will lead to the strengthening of GIS, for the arrow of benefit seems to point in that direction at the moment. The question is: what can linguistics and cognitive science 'say' to GIS to make it a more powerful, flexible and 'ready-to-hand' tool? Hence the Workshop.

It seems reasonable to assume, in this post-Winogradian and Floresian age,[1] that a pragmatic hope underpins such efforts; the hope that by taming to the linguistic, cognitive and cultural realms we shall be able to create much more useful computer systems to handle large quantities of locationally-specific data, and make these systems generally accessible to a large number of people. These will be working people--geologists, epidemiologists, commercial fisherman, people in local government, botanists, foresters, etc.--and few will have the time or interest to put anything but the most cursory effort into the intricacies of computer technology. Working people want systems that really are 'ready-to-hand'--like Heidegger's hammer[2]. They may want to use SPOT data for their own problem-specific inquiries and research, and they do not want to spend days, weeks, or months 'learning the system'. Life is too short, and they feel the time is better spent on questions that they consider to be more important. From a tool user's point of view this is perfectly reasonable.

Consider sitting with a working scientist at a terminal, a human being whose ability to inquire and ask imaginative 'what if' questions is enhanced by easy and rapid manipulation of large, and locationally indexed, data sets. 'Sets' is emphasized because it reminds us that they are composed of elements, and whether these are numerical or not there are only certain things one can do with them. In other words, geographic inquiry (using the adjective in the broad sense of any spatially situated inquiry), is already severely constrained by what the elements can be and what can be done with them when they are locationally specified. In this sense, GIS is a rather powerful intellectual filter. This is not a criticism but it is a fact. One that may be forgotten, or never realized and reflected upon, by those whose thinking must be similarly constrained and directed by the choice of the tool.

What can one do with sets of data, particularly locationally-specified sets displayed in map or picture form on a screen--a screen which, and perhaps importantly, also serves as a second filter by imposing its own technically-set resolution limits. No use having 3,500,000 pixels in the data set if the screen has a resolution an order of magnitude less (350,000, or 500 lines x 700 'lines'), although the finer structure may be recovered by asking for a blowup of a limited part. But what fundamental sorts of questions can we ask about sets with spatially specified elements? What can we expect from a machine and its GIS software? First, questions of identity. Sets can be partitioned into non-overlapping subsets. In other words, we can ask that an equivalence relation be imposed, and imposed willy-nilly. Where are the pixels[3] with grey tones exceeding 104 in Band 3? Where are the rice fields? Where are the eddies breaking off from the Gulf Stream to carry Caribbean energy to the Norwegian fjords? Where . . . where . . . where . . . always requiring a demonstrative answer . . . there . . . and there . . . and there. Partitioning with equivalence relations is the classical taxonomic act, and like the classical act of forcing things into boxes (equivalence classes), it brooks no ambiguity. Since we always deal with finite sets of elements composed of integers in empirical inquiry (which is what tools like GIS are for), making an

[1] Terry Winograd and Fernando Flores, Understanding Computers and Cognition: A New Foundation for Design (Reading, Massachusetts: Addison-Wesley, 1986).

[2] Martin Heidegger, Being and Time (New York- Harper and Row, 1962), p. 98 and half a dozen other references throughout the work.

[3] Using 'pixel' loosely for any spatial element or unit of a data set.

unambiguous rule is not difficult. You simply 'slice' the values with a 'greater than' or a 'less than', and a few more obvious variations on this theme. Of course, forcing equivalence relations on sets to partition them may destroy a lot of 'connective tissue' when more than one criterion is used, but this would lead us into other matters beyond this commentary.[4]

What else? We can count elements. How many pixels have wheat over Khazakstan? Which actually means: how many pixels have radiation values over the n bands lying between certain values that we think will discriminate the wheat over other things that 'sorta look like it'. Or how many pixels in eucalyptus? Or rather how many pixels in eucalyptus times some scalar to give us the answer in more familiar square kilometers or miles? Some people are comfortable in one, some in another, but I want answers to be meaningful to me so that I can think with them, so that I can 'picture' what they mean. Anyone who feels comfortable with Fahrenheit knows what it is like to go to a country with weather reports in Centigrade. Reported temperatures do not mean anything immediately, without a bunch of linear transformations of the sort "Oh God, do I add or subtract 320 before I multiply by 5 over 9 . . . or is 9 over 57. The 'how manys' from GIS have to be meaningful, not meaningless. Which points to what the observer brings to the terminal, what the context of the problem is, and what interpretation is made. Anything displayed on a screen is a 'text', and it is always meaningless without that hermeneutic act of interpretation. But before considering these context-specific matters, what else can we do with sets and their elements besides asking questions of identity (what is it), place (where is it) and quantity (how many)?

A few other things: first, we can do binary operations on the elements, probably the basic and familiar ones--addition, subtraction, multiplying and dividing. Taking them in reverse order, and grouping multiplying and dividing together,[5] we can 'Scalar' one set of elements (one map or picture) with another. For example, AIDS cases per population. These operations always give us 'Per answers. Notice that simple identity--'It's wheat'--does not generate a 'Per' question; we have to have integers as our elements. The same holds for what we might call 'set-map' A at t_1 scalar 'set-map' A at t_2 . This gives us a set-map of rates, usually expressed in the familiar percent integers, because we think nothing of scaling up by 100 to get rid of decimals. If they still insist on hanging around, and actually mean something, we can always scale to get permillages. Most practical problems will not need these: the error in the data makes them meaning-less. As for addition and subtraction, adding set-maps provides useful accumulation, providing we do not have apples and oranges; and subtraction (addition with a minus sign) provides useful differences, particularly if we have a set-map of integers at sometime 'before' and 'after'. Isolating and looking at change can stimulate questions. The simplicity of these familiar operations should not deceive: most of the questions asked of GIS are simple 'what', 'where', 'how many', 'what rate' and 'what change' questions. These operations also allow us to use all the familiar multivariate techniques, and all the spatially specific ones too, like computing autocorrelation functions. Although why anyone would want to do the latter is not clear: in the 25 years that they have been around, I have never heard of one being computed for any practical purpose or to solve any real problem. Much of the time set-maps will record presence or absence, and simple notions of set intersection will serve to relate one to another. Rather than a two-by-two contingency table, we might as well keep them 'on the ground' as geographic 'Venn diagrams'. We have raised, however, the question of relations between sets, and this might allow a rather different perspective on the traditional approaches. Relations between sets can form topological structures called simplicial complexes which serve to support other things, but this is not the place to review a large corpus of structural methodology,[6] even though it raises serious questions about traditional functional analysis and the thinking that goes with it.[7]

Finally, and because the set-map elements are locationally specific, any relationships will be scale specific, and we may wish to examine these to see if they are consistent and worth our attention, or ephemeral artifacts of the single scale of analysis chosen. 'Significant clusters' in epidemiology are a case in point, as Openshaw has so convincingly demonstrated with his GIS-backed

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[4] Peter Gould. Jeffrey Johnson and Graham Chapman, The Structure of Television (London: Pion, 1984), particularly Chapter 2 "Thinking About Classifying Television Programs", pp. T16-T28, of Television: The World of Structure, and Chapter 2, "Traditional classification and Partitional Thinking", pp. S38-S53, of Structure: The World of Television. See also Peter Gould. The Tyranny of Taxonomy, The Sciences, 22, 1982, pp. 7-9.

[5] Dividing is only multiplying by the scalar formed by the reciprocal. Let us call the combined operation 'scalar' and forget about the niceties of closure. Our sets are finite, with elements on the integers. Resolution of screen, accuracy of original observations. and the practical meaninglessness of many decimal places means we 'round and scale' answers back to integers anyway, so awkward irrationals and transcendentals simply disappear. They are mathematical conveniences, but nobody in the human sciences fiddles around with cosmological infinities or quantum constants.

[6] Ronald Atkin, Mathematical Structure in Human Affairs (London: Heinernann Educational Books, 1974), Peter Gould, A Structural Language of Relations, in Richard Craig and Mark Labovitz (eds.), Future Trends in Geomathematics (Pion: London, 1981), pp. 281-312. and Jeffrey Johnson, Q-Analysis: A Theory of Stars, Environment and Planning B, 10, 1983, pp. 457-470.

[7] Peter Gould, The Geographer At Work (London: Routledge and Kegan Paul, 1984), pp. 305-310.

Geographical Analytical Machine (GAM) focused on a real, and quite tragic, problem[8] It would be convenient, not to say scientifically worthwhile, to examine these things at 1, 4, 9, 16 ... pixel clumps. These are really filtering operations, and they point to the whole question of filtering: for example, local filters can 'smooth' a set-map by taking into account the geographical locations of elements, and a smoothed set-map can be subtracted from the original to serve as a high pass filter. And so on: these set-map operations have been around for 30 years.

What else? Well, what do geographers--using the term generically for anyone engaged in spatial analysis--traditionally do, either out in the field getting mud on their boots, or sitting in an armchair with a pile of maps and some colored pencils? They observe and point to things and ask 'what is there?' types of questions, either of themselves, or knowledgeable local informants. Census taking, the basis for so much geographic (again a generic use) inquiry, is essentially recording information in place. That is just about all you can do in the field. Back in the armchair, you can map the things you have observed and recorded; perhaps add points and draw Dirichlet regions to count things in them; or outline less formal geometric areas and color them in. Why? Because you think it might be important to distinguish them, and you want them to stand out. You choose colors in a way meaningful to you: hot reds-high values . . . cold blues-low values, or what ever suits you. You might add contour lines to help you think in terms of a surface of variation, gradients, rates of change, and so on. These are all mechanical-graphical tasks which can be achieved by using a mouse at a CRT--pointing, adding points, drawing geometric-specified lines, outlining, coloring by clicking from a menu-palette. Perfectly traditional tasks, now part of the standard repertoire of things we do on a screen. It took fifteen years to develop the mouse? It took 5,000 years to invent the wheel, but we do not have to start at the beginning each time we face the practical task of changing a tire. Mouses[9] are part of our 'world', within our horizon. Why not use them?

And that is about it.

But where does the 'cognitive science' come in? Does it matter for these practical, 'ready-to-hand', toolmaking purposes what the retina and optic nerves are doing? Does it matter what cells are firing in the hippocampus? Notice this says nothing about the intrinsic interest or intellectual worth of understanding the physiology of vision. It simply raises the question of whether we need to start there. What else in cognitive science could inform the practical task, a task that underpins and informs the intellectual task, the task of thinking? Thinking geographically (generic: use again) is intentioned thinking towards some-thing or towards people--who are definitely not things.[10] It is thinking directed to bringing out into the light of human knowing that which was not seen before. What can cognitive science, by its own admission a very young and naive science, add to GIS to enhance thinking? By which we presumably mean helping us to see more clearly and imaginatively and creatively. But cognitive science, which immediately moves its own thinking away from the human being towards a mechanistic model-dozens of different models--can say little about creative human thinking when it so desperately needs it itself. I am reminded of a comment made recently when something went wrong in an atomic power station. The reason-excuse given by the 'management spokesmen' was that the "mental model was faulty". But the critic, who respected language and reason, pointed out acerbicly that the notion of a mental model was simply irrelevant and superfluous. Either the operators knew what the situation was and what to do about it . . . or they didn't. No 'mental model' was involved. In fact it only got in the way by hiding the real problem. Do we face a somewhat analogous problem with cognitive science, and the apparent difficulty it has contributing to the design of more flexible GIS? The basic problem is that it immediately directs thinking to the machine. Human thought is treated in purely mechanistic terms in a series of models that change all too frequently, and simply mirror the mechanical possibilities currently available. Parallel processing appears in computer design, and immediately 'this year's model' in cognitive science becomes a parallel processing brain. As Searle has pointed out, this sort of mechanical thinking has a long history:[11] since the 15th century, the human 'mind' has been likened to a flour mill, a hydraulic system, a telephone exchange, a sequentially processing computer, and now a parallel processing computer. As long as you are trying to design machines to pick up nuts and bolts and stick them in the right place, no harm is done and you go with whatever works. But cognitive science first conflates the human with the machine, immediately forgets that it has done so, and then leaves the human being behind. The result, to an outsider, is a highly repetitive, almost cannibalistic literature in which everyone reviews and footnotes everyone else without conveying much sense

[8] Stanley Openshaw et at., Building a Mark I Geographical Analysis Machine for the Automated Analysis-of Point Pattern Cancer and Other Spatial Data (Newcastle-Upon-Tyne. Centre for Urban and Regional Development Studies-CURDS, New Castle University, 1987).

[9] Presumably correct when referring to everyday tools--like a tailor's goose?

[10] 0nce we confuse the two, human beings and things (like machines), we are lost, morally, ethically and even scientifically. Reifying ('thingifying' in Olsson's more pungent and direct phrase) people, blurring the distinction, leads to horror on the moral plane, and sheer stupidity on the scientific plane. We might even end up designing GIS machines for mechanistic models instead of people.

[11] John Searle, Minds Brains and Science (Cambridge, Massachusetts: Harvard University Press, 1984), the published Reith Lectures of the BBC for 1984.

that any advance has been made. One wonders to what extent cognitive science creates its own, and perhaps quite false, problematic by posing the existence of schema which have no reality. To what extent does a mechanistic cognitive science feed on itself and leave the rest of the world outside of its own rather incestuous boundaries? And to what extent can these self-generated and self-engaging problematics actually inform the real and thoroughly practical task of designing better, more ready-to-hand' GIS? The problem is that GIS is a machine system that must be suitable for a person, not another machine, and not a person treated as a machine. People are not robots programmed to a task, but beings with a capacity for intentioned inquiry that tries to bring that which was not 'seen' before into the open clearing of human thinking and understanding. I take it that this is precisely one of the things that Winograd and Flores were pointing to: we are building mechanical systems to help people, not other machines. This does not say that we should not examine cognitive science, and ask what is known with reasonable surety that might be of use in the thoroughly practical task of GIS toolmaking. But it does require that the knowledge base of cognitive science is systematically and critically examined in light of the GIS -construction task to see if there is much it can contribute.

What about linguistics? Examples from many languages, particularly the prepositions, locatives, and demonstratives, sensitize us to the rich designative possibilities appearing in language, and such heightened awareness might be useful. But under what circumstances of inquiry would the generic-geographer ask 'Is X in front of underneath . . . on top of . . . behind . . . Y?'. In 30 years of research and reading, I cannot recall a single question of this sort. People do ask questions of contiguity, of 'next to', but these require no 'ups and downs' for either the questions or the answers. In the initial, what we might call 'ruminating' stages of informal and preliminary inquiry, generic-geographers do ask 'Is X near Y?' (are the cholera cases near the pump?), but this is only a rough musing preceding a careful, and always context-specific operational definition of 'near', a definition informed by looking at the map or screen. For all the ingenious, in-the-church examples[12] that can be contrived to highlight the fact that different frames of reference may be in use and producing ambiguity, who, and under what research circumstances, would actually ask 'Is X in front of Y?'. You can actually see X and Y, and all the other bits and pieces of interest on the screen: how does this become a problematic raised to the intellectual level of a research question? Naturally, it is desirable to be sensitive to linguistic variation, especially those instances that enlarge our own horizon beyond the familiar languages that shape our own thinking. But even as our sensitivity to the conditions of locative possibility grow in Balinese, would it not be practical to start with what we know? Indeed, can we, as twentieth century GIS-intentioned geographers, start with anything else? This is not ethnocentricism, but a simple and straightforward acknowledgement that we live in our own familiar 'world' shaped by our language. It is this that gives rise to creative possibilities, for we think in language, and the locative suffixes employed by the people living in an interior valley of Papua do not shape such thinking by us.

Of course, there may be other sorts of information systems for which linguistic 'conditions of possibility' may rise more directly. The Aranda of northern Australia may wish to store their songlines in a PC, and incorporate their own spatial terms and references in an interactive retrieval system. But this does not appear to be a pressing problem to which scarce scientific resources should be directed at the moment.

What does emerge again and again, and in various forms, in thoughtful and practically directed discussion about GIS is that any such system poses essentially a technical problem. In other words, it lies in Habermas's 'technical perspective'[13], and is a device for the creation of texts-pictures, maps, etc. Highly creative and imaginative geographers tend to display a marked capacity for generating provocative visual 'texts' from unusual perspectives that have not been thought before. By definition these cannot be prespecified and preprogrammed: all one can do is provide the technical conditions of possibility for their creation. Even so, the texts are inanimate things without meaning unless interpreted and given meaning from the wholly human hermeneutic perspective. Obviously the creation of a technically possible text is not necessarily divorced from some anticipation of the possibilities of interpretation, although we also recognized in the very word 'serendipity' the possibility of being completely surprised. Both the technical and hermeneutic tasks may be jointly informed by Habermas's third, or emancipatory, perspective, a sense of caring of the sort that presumably underpins Openshaw's research on childhood leukemia, as well as the work of many other geographers. But such personal motivation need not detain us here: the point is that both the technical creation and the hermeneutic interpretation are acts of human beings not machines. Linguistics at least draws our thinking back to language as a condition of possibility of being human. A cognitive science which immediately substitutes a reified machine for the human presence, and its concomitant and constitutive capacity for illumination, appears to have forfeited the ability to inform a GIS. It may speak of a human-machine interface, but it seems to lose its capacity to keep the 'human' in sight.

Pointing to the human act of interpretation giving meaning to a text simply reinforces the importance of a statement and conclusion that appeared again and again in the workshop discussions. Namely, every text-creation, and every meaning-giving

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[12] An example constructed for the Workshop that generated great and purposeful ambiguity by having four possible 'frames of reference' in a small space, the interior of a Christian church.

[13] Jurgen Habermas. Knowledge and Human Interests: A General Perspective, inaugural address, June 1965, University of Frankfurt, in <u>Knowledge and Human Interests</u> (Boston: Beacon Press, 1971), pp. 301-117.

interpretation, is context dependent. This means it depends totally upon what the problem is, and who is doing the interpreting. By definition there are no generalities here: it depends on what is the focus of inquiry, and what the inquirer brings to bear in terms of prior knowledge and experience. That, presumably, is why some people have a 'knack' for seeing things that others miss, why some geographers are better geographers than others. And it is no good thinking about eventually incorporating all their experience, imagination and 'nose' for a good problem into some expert system. Original research, by definition, is seeing what has not been seen before. It is not a combinatorial rummaging through the bric-a-brac of past templates to find something that fits, but an act of human creation that lets people say 'Oh, I see!', where no seeing was possible before.

This has two implications, one directed to geographic research, the other to geographic education. In research the truly important element is the inquirer, and anything that gets in the way of free and technically unhampered inquiry can only have a constraining effect upon original research. This means that any GIS should be designed so that it can quickly be made personal, so that it becomes the inquirer's own system that allows, perhaps even encourages, free and flexible experimentation. We already know that by choosing GIS as a tool we already constrain severely the possibility of asking important researchable questions. What can be asked is immediately limited by sitting down at a terminal, and the same constraint is imposed upon insights that can be 'mapped back' into thinkable language. There are more things in heaven and earth than those that fit into the limitations of a GIS, but at least within the inevitable constraints the possibilities for 'free play' should be optimized.

The second implication is educational. More and more we are beginning to see the sheer technicality of GIS making greater and greater demands on student time and university resources. The ever-bigger GIS tail is wagging more and more strongly the geographic dog. Many have experienced the results, not the least the sight of undergraduates spending scores, if not hundreds, of hours in front of CRTs learning the technicalities of a system, but at the end of it all finding, distressingly little creative and illuminating use for all the computerization. It is very much like the old days, when hundreds of student hours at a field camp went into the construction of a land use map, even though no one knew what to do with it when it was finished except hang it on the wall of the department for decorative purposes. The technical task of text creation is seen as an exercise and end in itself, with little apparent thought for the hermeneutic task, or the emancipatory motivation of understanding the world and the human condition.

In brief, GIS at the moment is so primitive, possesses so little flexibility, and it is so user unfriendly, that students are forced to spend hour after hour, and course after course, learning the specific intricacies of a local system, leaving little time for the content of physical and human geography (or geology, meteorology, or whatever the spatial science of concern) that constitutes the wellspring of possibility for generating real and researchable problems and deeper understanding With increasing and distressing frequency, students choose from the limited set of questions that allow them to use a GIS, rather than choosing problems of some genuine intellectual value, making genuine intellectual demands, whose analysis may (or may not) be enhanced by rapid manipulation of locationally specific data sets.

Many students are drawn to this highly structured and inflexible training because they see a job at the end of it. But we are beginning to get some interesting feedback: first, the jobs are rapidly becoming saturated; and secondly, and more importantly, those hiring students trained in these geoengineering sequences are beginning to realize that technical expertise was not what they were really looking for after all. "We can train people in our own local system in fairly short order", they say, "But what we really want are educated geographers who can ask the right questions, and raise all those interesting possibilities that economists and sociologists and psychologists never think of."

But these sorts of comments point in a quite different direction for geographical education than the lockstep of courses through which so many students are now marched, with little freedom to choose to widen their geographic horizons and the problem-generating possibilities that come with such exposure to substantive geographic content and a variety of methodological approaches and perspectives. Even 'supporting courses' only support and reinforce the technicity of their world, not the substantive and imagination-producing geographic content.

Sitting in the stands, pointing a thumb up or down, is always much easier than fighting the beasts down there in the blood and sand of the arena. From the outside looking in, progress seems to have been made with agonizing slowness towards anything that even faintly resembles a flexible, user-friendly GIS genuinely 'ready-to-hand'. One wonders what is holding things up when so much has been achieved in adjacent areas, and when so many other possibilities are taken for granted today. Huge data sets are handled, filtered and enhanced by JPL every day, backed by computers that are large and fast by even today's standards. Does this say that really large data sets require really large computers, and that academic programs may not be the most suitable place to work with them? Or do we have faith that larger, faster, and cheaper (?) computers will come along so that flexible GIS, designed for people not machines, is just around the corner? If capacity constraints are severe in the academic world, does this mean that thinking is led to the minutiae of algorithmic nicety to chop off a few seconds here and there, but then forgets the much more important tasks of inquiry in the physical, biological and human worlds for which a GIS is created in the first place? Does the technicity of GIS become an end in itself, or is it always seen as a means to an end? And will students (or professors for that matter), recognize the end when they see it?

As for using the possibilities available, it was with consternation that I learnt that using all the potentialities of the demonstrative mouse was apparently considered something new and tricky. Did I really understand the responses correctly? That "it's all very well, but the mouse took fifteen years to develop…"? The Open University, in its Center for Configurational Studies, has just produced seven highly imaginative units for its undergraduate course in computer aided design-combinatorial search (space packing), the design of logic circuits with LEDs, and so on. All units use the mouse-menu format as a matter of course. They were designed by a man who rolled up his sleeves and got down to it, designed the units, wrote the requirements in BASIC to get a feel for the problems, and then turned over the final programming task to experts who tightened everything up for rapid interactive display. There are very experienced and gifted people in interactive programming, many of them in the commercial world with abilities to produce graphics that blow the academic stuff out of the water. Perhaps we should tell them what we want, give them a chunk of NSF money, and ask for the results?

But do we know, really, what we want?