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USER INTERFACES FOR GEOGRAPHIC INFORMATION SYSTEMS: DISCUSSIONS AT THE SPECIALIST MEETING

compiled and edited by

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1. INTRODUCTION

> *"Are users really necessary?"*
> Selected as the quote of day 3 of the meeting

This report describes discussions at the Specialist Meeting of Research Initiative 13, "User Interfaces for GIS", of the U.S. National Center for Geographic Information and Analysis (NCGIA). As participant Will Craig of the University of Minnesota pointed out in commenting on a draft version of this report, the report contains many ideas throughout, and thus no summary or abstract could do justice to the contents of the Specialist Meeting. Thus we advise against skipping to the summary, and instead suggest that those who cannot read the document word-by-word should skim through the entire document to get an impression of the topics covered.

The problem of Human-Computer Interaction (HCI) for Geographic Information Systems (GIS) has been noted in the GIS literature (see especially Porter, 1986; Gould, 1989; and Mark and Gould, 1991), but has recently been highlighted by the NCGIA. The Specialist Meeting for Initiative 13 was held June 22-26, 1991 in western New York. Of the 41 official participants in the meeting, about three-quarters were from the GIS community, and one quarter from the HCI community. Fifteen participants had attended at least one earlier NCGIA Specialist Meeting; also, 12 participants were from the private and public sectors, and 29 were university-based researchers. Eight of the official participants were graduate students, five from outside the NCGIA. The participant list, with affiliations, is included as an Appendix to this report.

The Specialist Meeting began with a half day on the campus of SUNY at Buffalo. Following introductory remarks and background information, the participants spent several hours in the Geographic Information and Analysis Laboratory (GIAL) viewing software demonstrations, mainly by participants. The remainder of the workshop was held at a conference center in Chautauqua County, New York, about 90 miles from Buffalo.

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The meeting alternated between working group sessions and plenary sessions. The working group sessions provided opportunities for focussed discussions on narrowly-constrained topics by 6 to 10 self-selected participants. In the plenary sessions, representatives of the working groups presented summaries of the groups' discussions and findings to the entire group. On the final day, working groups defined an agenda of researchable questions on a six-month to two-year time scale. Longer term research issues were raised and recorded, but mainly to provide further perspective.

David Mark and Andrew Frank, the Co-Leaders of Initiative 13, opened the meeting. Frank indicated that it was inappropriate to start with a discussion defining a GIS as most of the participants had extensive experience in the area. The demonstration of actual geographic information systems can serve as a pragmatic replacement for a concise definition.

Why is the discussion about user interfaces for GIS timely? Fifteen years ago, producing maps with computers and computing overlays was a major achievement. Now this can be done routinely. However, in the past the question of how these systems would be used was rarely addressed; it was enough just to be able to do these tasks and some rudimentary spatial analysis. The general attitude was one of 'miraculous computers' and dumb users—and users were inhibited from admitting problems and errors. Now the frontier is being pushed back, and convenience for the user is becoming most important. The cost of educating users in the use of a new system is currently estimated to be of the same order of magnitude as the acquisition of hardware and software. The rapid growth of system functionalities, as well as the growth in the numbers of users and the variety of user communities, means that usability concerns become primary. The user is now the most important consideration in system design. Recently, one company responded to this situation by doubling the size of its software's user manuals—this does not seem to be optimal progress towards better usability of GIS! Instead, it clearly shows that a usability problem exists today. Systems often do not perform the functions the users really want, and the users do not know how to translate their needs into operations the system can execute. Systems should generally be designed by first asking what the interface should be, then building a system to support it, not vice versa. The position papers for this meeting approached the issues from a high level perspective, and left the details for later. This is exactly as it should be and we hope that the resulting research will start at this high level and work backward to the details.

David Mark commented that there were still many unsolved technical issues, but that the usability issues are now highlighted. At the May 1991 Environmental Systems Research Institute (ESRI) User Conference in Palm Springs, consumer advocate Ralph Nader gave a keynote address on public access to information. It is of little use if a government agency or large corporation complies with "access to information" regulations by supplying the citizen with a digital data tape in a proprietary format. To meet the spirit of "access to information" regulations, organizations will need to deliver easy-to-use software to allow 'citizen-scientist' end users easy access to the information. Nader suggested that usable GIS could play a key role in providing information to the public. But this can only be achieved if the GIS user interface can communicate with a lay person, rather than requiring months or even years of professional training.

1.1. Expectations for this Workshop

Frank briefly stated his expectations for this Specialist Meeting. From an engineering perspective one would wish for directly applicable rules and guidelines that lead to usable interfaces. Enormous progress in user interface design was made when Apple Computer Corporation published its guidelines for the Macintosh Interface (Apple Computer 1987). The guidelines defined a consistent style for a user interface, independent of a specific application, and allowed users to transfer knowledge acquired with the use of one program to others, thus shortening learning and improving usability. Could we produce similar guidelines for GIS user interfaces, which could be applied across application areas, platforms and products?

A number of specific questions are related to the results from research in spatial concepts (Mark and Frank 1989; Mark *et al.* 1989; Mark and Frank 1991):

1. How do spatial concepts influence the usability of GIS?
2. How does the fact that GISs have predominantly been developed by 'first world' speakers of Germanic languages influence usability by people from other language groups and cultures? Are there aspects of the way certain products handle space that makes them difficult to use in some cultures, e.g., in southern Europe?
3. There are at least four classes of GIS users. Novice users want an intuitive, easy-to-learn system; casual users normally cannot remember arcane commands; expert users may have no interest in computers; and system designers are often not familiar enough with actual use situations. What are the different interface issues for these four groups?
4. What paradigms do we use in design? Is the concept of "virtual reality" influencing GIS interface design?
5. What channels should we use for interaction? Should bad data smell like bad cheese? Can we multiplex data through several channels?

A common question underlying all these concerns is *what is special about spatial data?* This should be the basis for I-13 research, and discussions about general user interface issues should be limited to cases where there is a need from a GIS perspective. At a workshop on "User Interfaces for GIS" at CHI '91 in New Orleans, Brad vander Zanden raised that issue by asking if and how spatial data were different from other data. To us, it seems that both the data and the tasks are different, but it proves quite difficult to pin down exactly what the differences are. Certainly there are GIS-specific user interface issues in vehicle navigation systems, in navigation systems for the visually impaired, and in a wide range of other areas. But it is not clear whether a large proportion of general GIS tasks also occur in other disciplines.

Frank concluded the opening session by saying that GIS tends to uncover demands on information systems long before mainstream applications discover them. This happened in the early 1980s with database systems and is now also happening with user interfaces. The results from this research initiative will have applications beyond GIS. The role of spatial cognition as a source of metaphors for abstract reasoning is so pervasive, that issues discussed at this meeting will have applications to non-spatial information processing as well.

1.2. Previous User-Interface-Related Activities at NCGIA

Other NCGIA research initiatives have been dealing with questions related to human-computer interaction and user interfaces. As the initiatives have been designed to follow in a sequence where later ones build on previous ones, a brief review of some of the previous initiatives is appropriate.

1.2.1. Initiative 2, "Languages of Spatial Relations."

This Initiative covered questions about formal descriptions of space, and how people think and communicate about space. At the I-2 Specialist Meeting, the distinctions and relationships between spatial concepts, spatial data models, and spatial data structures were clarified. Results from I-2 were presented and discussed at a NATO Advanced Study Institute on "Cognitive and Linguistic Aspects of Geographic Space." A book from that institute has been published (Mark and Frank, 1991), and includes five papers that specifically address user interface issues. The findings of I-2 are especially important for user interface design issues in GIS. GIS user interfaces revolve around the users concepts of space and spatial objects, and it is critical that the system deal with space in a way that the user can relate to.

1.2.2. Initiative 3, "Multiple Representations."

Initiative 3 dealt with questions arising from the need to have multiple representations of space (e.g., space at different resolutions) in one system. I-3 has specifically addressed cartographic generalization problems (McMaster and Buttenfield, 1991). Multiple representations, both in databases and at the user interface, are crucial for effective human-computer interaction.

1.2.3. Initiative 4, "Use and Value of Geographic Information in Decision Making."

Although I-4 did not specifically address Human Computer Interface (HCI) issues, it relates to Initiative 13 covering topics of public access to Geographic Information Systems. The major tenet is that geographic information is only as valuable as it is usable, thus the user interface is relevant, as it is a precondition for the effective use of the data collected (Onsrud *et al.* 1989).

1.2.4. Initiative 5, "Architecture of Very Large Spatial Databases."

A relevant outcome from Initiative 5 was that user interface issues received more attention than expected. The discussion repeatedly focused on how to make the user aware of what data are in a database, and how they can be accessed (Günther and Buchmann 1990; Smith and Frank 1989). (This was also a central topic in Initiative 12 on Remote Sensing and GIS.)

1.2.5. Initiative 6, "Spatial Decision Support Systems."

User interfaces are also a critical part of SDSSs. The quality and timeliness of spatial decision making are a direct function of the adequacy of user interfaces for these systems. Spatial Decision Support Systems are by their very nature highly interactive (Densham and Goodchild 1990).

1.2.6. Initiative 12, "Remote Sensing and GIS."

Access to large databases on satellite images, especially browsing, was also identified as a central topic in Initiative 12.

1.2.7. Initiative 7, "Visualizing the Quality of Spatial Information."

Initiative 7 conducted its specialist meeting about two weeks before initiative 13. Initiative 7 is treating a specific human-computer interaction problem in depth: that of how to communicate quality aspects of spatial data to their users. The topic has practical implications—in a recent book (Monmonier 1991) it was noted that people have been lying with maps better and longer than they have been lying with statistics (Beard and Buttenfield 1991).

1.2.8. Initiative 13 Workshops and Panel Discussions

The way for Initiative 13 was also prepared by several special sessions at professional meetings in 1990 and 1991. These included a workshop at CHI '90 on Visual Interfaces to Geometry (Kuhn and Egenhofer, 1991), a Special Interest Group on GIS User Interfaces at CHI '91 (conducted by Kuhn and Mark), two panel sessions at the 1991 annual meeting of the Association of American Geographers (organized by McGranaghan and Mark), and a panel discussion at the 1991 ESRI User Conference (organized by Gould and Mark).

1.3. Software Demonstrations

In order to provide some concrete examples of existing GIS user interfaces, there were five software demonstrations at the SUNY-Buffalo Geographic Information and Analysis Lab

(GIAL). These were especially impressive in that in no case was the software running at Buffalo before the workshop.

- Kurt Buehler presented a direct manipulation user interface for the GRASS GIS product. In this case, a Sun hard disk loaded with the program and data was shipped to Buffalo; it was attached to a Sun in the GIAL, and the Sun was re-booted from the disk.
- Joe Ferreira showed an Urban Planning System that can be run over a network. (The demonstration was actually running on a Sun back at MIT, some 600 km away.)
- Jeff Jackson demonstrated ArcView, a new ESRI software product for interacting with ARC/INFO databases. Jackson brought a Sun CPU as carry-on baggage; the GIAL provided the keyboard and monitor.
- Bruce MacDougall presented an operational prototype for exploration of spatial data on the Macintosh through statistical visualization and dynamic graphics
- Jonathan Raper gave a demo of HyperArc, a HyperCard program running on his Macintosh portable, that provides a front-end for ARC/INFO running on a host machine (in this case, a VAX at SUNY Buffalo).

1.3.1. Short Presentations of Specific Projects

Three short presentations of specific projects were made Monday afternoon:

Östberg introduced MITI's FRIEND 21 Project from Japan. It is based on a generic television metaphor, allowing users to choose their favorite TV show as a metaphor source for application tasks. There is an anchorman in the lower right corner of the display who acts as a liaison between the user and the internal model (Nonogaki and Ueda 1991). Part of the project is building a Japanese standard for user interfaces.

Two video presentations were shown. Shapiro presented CUBRICON, a natural language, map-based, multi-media system developed at SUNY Buffalo (Neal *et al.*, 1989; Neal and Shapiro, 1991). The second video, presented by Steve Smyth, was a demonstration of a virtual reality combat simulator.

2. STRUCTURING GIS TASKS

Sunday afternoon and most of Monday were devoted to discussion of GIS tasks. One of the major results from the meeting was the recognition of an urgent need for a classification of GIS tasks. It was observed that many of the decisions during the design of a GIS interface were strongly influenced by the task the user wants to perform.

2.1. GIS Tasks in Different Application Areas

Frank started the late Sunday session with the question "What is special about spatial data?" He asked the participants to focus on tasks that are specific to GIS and to spatial data-handling. The participants were to break out into four smaller groups to collect and discuss such tasks. The result of the sessions would be small lists of user-level tasks that are typical for this application area. These could then be used by human factors specialists and others as guidelines for research.

Martin Helander provided some background for the session. People who work in human factors typically test users in real work situations. This is done by

- collecting performance data,
- thinking about the tasks, and
- studying errors people make.

In general, one differentiates between strongly structured and unstructured tasks. A common strategy is to break down tasks into levels of abstraction. It proceeds from abstract functions to the physical functions and their form. The HCI community has not yet studied GIS tasks.

Frank's intent for the group sessions was to look at abstract functions that people perform. Three examples are overlay, pan and zoom, and finding a place on a map. He suggested that each group attempt to come up with 6 to 12 tasks. The goal of this exercise was to define questions for the HCI community and others.

Several participants raised questions about the exact meaning of this task notion. The definitions of goal, task, and function were brought up (Raper and Bundock 1991). Is a functional taxonomy of GIS capability needed? If the function set for GIS is stable, should the focus be on user's needs (Lanter and Essinger 1991)? Should tasks be discussed at a higher level? Does the user really want to do "pan and zoom" or is this notion only an artifact of today's systems? Turk suggested that the appropriate task taxonomy dimensions, hierarchy and granularity may be determined by the chosen HCI theoretic model and task analysis procedure.

2.1.1. *"Planning and planning-like applications," reported by Will Craig*

What are the tasks in planning and planning-like applications? There are many ways to look at this issue. The first problem is to decide whether to consider Planners with a capital 'P' (that is, professional planners), or planners with a lower case 'p' (that is, anyone who makes plans). The former were chosen.

There are certain routine planning tasks that are easy to implement today; "someone just needs to write the AMLs[1]". For example,

1. Determining whether a given building permit application was in conformance with zoning;
2. Creating a mailing list for a notice to be sent to adjacent land owners;
3. 'Cook book' planning tasks such as environmental impact analysis, e.g., collecting data, organizing it, and presenting it according to stated rules;

Other tasks are non-routine. For example, exploratory analysis and design; identifying emerging problems; allocation of space to a 'locally unwanted land-use', e.g., a jail. They involve, however, a few general steps that may be identified as typical tasks for professional planners. Each of them can or could be helped by a GIS:

1. Exploring available data (planners often have no data collections of their own; therefore it makes sense for them to tie into available data).
2. Extracting and transforming those data. Data are not usually in the right form; therefore they need to be reworked, summarized, etc. Examples include address matching and aggregation.
3. Discovering solutions. This is usually done with diagrams, pencil and paper. Frequently, there are multiple iterations. One idea is to start with a solution and see how a GIS could have supported it.
4. Generating high quality maps and diagrams. This is an education and persuasion task; the results must be communicated to an audience.

2.1.2. *"A Natural Resources Environment," reported by Dana Tomlin*

What are the tasks in a natural resources environment? The group identified five "players" in the process of resource management. Listed in order of increasing problem difficulty, they are the scientist, the engineer, the warden/manager/person-in-the-field, the politician,

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[1] AML is the " ARC Macro Language" within ARC/INFO.

and the public. For each player, the group determined what GIS technology could do for them and what qualities of the users are important.

The *scientist* is the repository for multiple representations of data, and her task is primarily to create models of processes. They are generally based on smooth space-time transitions.

The *engineer* does not just need to know about processes, but has to act on this knowledge and make decisions. He tries to use data that the scientist has collected for design work. In his design, he must consider both that the data are uncertain (and therefore there is some risk), and that the implementer would not necessarily do a good job.

The *warden* is in the field on a day to day basis. She is confronted with (and has to reconcile) discrepancies between the database and the real world. (Wouldn't it be nice if this person were able to correct the database in the field?) An idea of Nick Chrisman's from the Initiative 7 meeting was mentioned here: If wardens were given small head-mounted displays, which would overlay the GIS data and their field of view, they could see both 'reality' and 'GIS' and immediately fix discrepancies, perhaps using a 'virtual reality' mode of interaction—just 'grabbing and moving' the pipes (in the GIS) to make them conform to reality.

Since the *politician* is a policy maker, he has to reconcile differences between supply and demand, relying on data from the technical community. He poses a problem to the engineer and then has to account for any differences to the public. There is also a connection with the warden in an administrative role.

The *public* (as client and landowner-citizen) wants information and needs appropriate visualizations and plans. It usually acts in groups and needs to be able to use the technology to state its case. This is difficult because emotional connections of certain groups to particular spaces and phenomena in space cannot (yet) be accommodated in a GIS. The public interacts mostly with the warden and the politician, rarely with the engineer or the scientist.

Tomlin felt that these players were a necessary and sufficient group for looking at tasks. Others (Turk, Östberg) questioned whether the operators and assistants who actually use systems for these players should not have been included. One might even add the software developers, as another group of "indirect" players.

The connections between players are not linear. A GIS serves as a link not only between data and players, but also between different players. The process models are as much a part of the GIS as data are and must be linked. It is especially important with naive users that the data "speak for themselves." A problem with realistic models and representations is that they often appear to be of higher quality than they are. Also, many important phenomena are fuzzy. In soils, the transition from gravel to loam is not a sharp line, but an engineer builds structures that have sharp lines. These inherent discrepancies must be accounted for.

Some participants held that interfaces should *stimulate* the public. One cannot present information without giving a viewpoint. The animations in the GISTutor tell a story, and therefore capture attention; however, whether the public actually gets information from such techniques is another question to be answered from the HCI literature or from experimentation. Golledge asked whether the public generally understands the information it is supposed to get. A research question is how much and what kind of information people actually acquire from the presentations they receive. This also raises the possibility of yet another important player in this scenario—the press, who often provide most members of the public with their only link to the scientists, engineers, *and* politicians.

2.1.3. "Spatial Decision Support Systems," reported by Marc Armstrong

What are the tasks in Spatial Decision Support Systems (SDSS)? In order to overcome the imprecision in the understanding of 'task' and a large group, the SDSS group decided to use example problems.

Most SDSS tasks fit in with Helander's category of ill-defined and unstructured problems. It is difficult to determine a well-defined set of steps to solve them. For example, take a location analysis problem. Do you build two or three fire stations to optimize various fire response variables? The factors to take into account may vary from town to town.

The first example problem was where to *locate cellular telephone transmission towers,* how to orient antennas, what power to give them, and how to design and model the network for optimum performance. As mobile telephones are concentrated in areas of high traffic volume, this is a dynamic problem. Inputs are a radio propagation model and actual ground measurements of signal strength. The modelers need to ask questions like how high to make antennas, how big to make coverage areas (cells), and how much volume a given cell can handle. System users for this problem are process engineers who develop models of expected system behavior, planning engineers who actually place the tower, and customer service personnel, who field complaints from users. Three categories of these users were considered: naive users; applications people or "SAPpies"[1]; and system designers. In addition, these users would need to work together. In Computer-Supported Cooperative Work (CSCW), the goals and objectives of various users are taken into consideration. Specific sub-tasks were identified: identify demand/supply locations; locate antenna site; and allocate area to point.

The discussion moved to combining different functions, algorithms, etc. to form new functions. There is a need to accumulate analytical functions into tools. One could use a model-based management system to do this.

Buehler introduced the example problem of designing an *Army Training Task*: Design a system to assist in planning optimal training procedures, given a certain area, weather conditions, training requirements (e.g., amount of realism needed), environmental impact guidelines, safety boundaries for artillery, and other conflicting uses. Specific tasks would be

- allocate an area to a point
- evaluate a training plan
- identify demand for points of use
- specify a candidate location
- display maps which show results of model
- determine a study area

Lanter then described a system *to plan wood cutting* he had worked on for the U. S. Forest Service. The system replaced a printed data report generated by a model in the MIS department. The report would indicate how much wood to cut, but the model was inaccurate. Lanter's system took the printed data and displayed it in color, and then applied two models:

1. show result of spreading damage over all compartments
2. reduce cut to sustainable levels for all compartments

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[1] Spatially Aware Professionals—this term was introduced by Jonathan Raper and his Birkbeck colleagues in several papers on user interfaces for GIS.

Specific tasks would be

- determine what model was used to support a decision (audit trail)
- find an optimal answer.

Turk stated that user-system interactions at this level are too complex for existing task analysis procedures. For instance, the 'levels of cognitive control' approach requires that general process objectives be decomposed to particular cognitive tasks. It is based on Rasmussen's theory of levels of cognitive control (Rasmussen and Jensen, 1974; Rasmussen, 1986) which is not easy to apply. In particular, we often do not know what mode of cognitive control we are dealing with. McMaster compared this with GOMS analysis (Card *et al.* 1980). There are only very limited parts of a well defined, strongly structured task that are analyzed in great detail. GIS as a whole must first be broken into smaller, more homogeneous pieces.

2.1.4. "Remote Sensing and Image Processing Applications," reported by Jeff Jackson

What are the Remote Sensing and Image Processing tasks? The most general task is to derive models of the world. However, the user's model and the system model are particularly far apart in image processing applications, one being for example land use categories, the other being the signal strength observed in different wavelength bands. The two models need to be brought closer together; ultimately, the system model should disappear.

Users want to transform data into information, i.e. into something which answers questions they have. They need to know:

- what data there are
- where it is in the world
- how it relates to other data.

Like planning tasks, determining what data are available is a problem in organization management and categorization of data, lineage, metadata, etc. Many of the basic operations in image processing are well understood, but it is not clear how to present them in a comprehensive manner to the user. The problem is aggravated in remote sensing by the huge data volumes. Ellis pointed out that handling these very large data sets poses technical problems, which limit the freedom to design user interfaces from a conceptual level. The following problems are posed in particular:

- How does one present the location of data to the user in an easily-understood way?
- How does one set of data relate to another?
- Is looking for correlations a task that is typical for GIS?

2.2. HCI Theories for Task Analysis (Monday Afternoon)

2.2.1. Cognitive Task Analysis

Martin Helander began the afternoon session by giving a presentation on cognitive task analysis.

Following the methods advocated by Jens Rasmussen, there are three categories of human behavior that are relevant for modeling the cognitive processing involved in performing tasks. The first level is *skill-based behavior*, in which tasks are performed automatically, with no conscious information processing, e.g., braking an automobile. The next level is *rule-based behavior*, where one goes through a set of steps to determine action. If the foot break fails, one has to step to the next means of stopping the car, namely the emergency brake. Finally, *knowledge-based behavior* relies on the development of complex patterns that must be interpreted and applied in a given situation. It involves reflection, optimization, etc. If the emergency brake fails, one must steer the car appropriately, shift down, and apply judgments based on one's learned understanding of automobile physics.

The level of cognitive control adopted by the operator may be influenced by the context (creativity, knowledge, available rules, acquired skills, naive reasoning patterns). For example, for operators trained in digitizing, closing a line is a task at a skill-based level in general (done without thinking), but it becomes a task at the knowledge-based level, if something goes wrong (e.g., if there is not enough disk space to store the next point). Further, knowledge-based situations arise when the situation is unfamiliar and previously learned rules do not apply.

Rasmussen was concerned with systems for controlling nuclear power plants. In those kinds of environments, one strives to avoid knowledge-based tasks for operators. One technique used in controlling such complex processes is mapping complex sets of variables about processes to a simple display. This can make knowledge-based operations become rule-based. There is a general need to support changes in task levels. Understanding tasks in GIS within a Rasmussenian framework is a promising research direction.

Design can be approached top-down or bottom-up. Top-down design is simpler, because it can be based on rules. Bottom-up design is rather knowledge based, because the problem fans out as one proceeds. An example of a top down design approach is shown below.

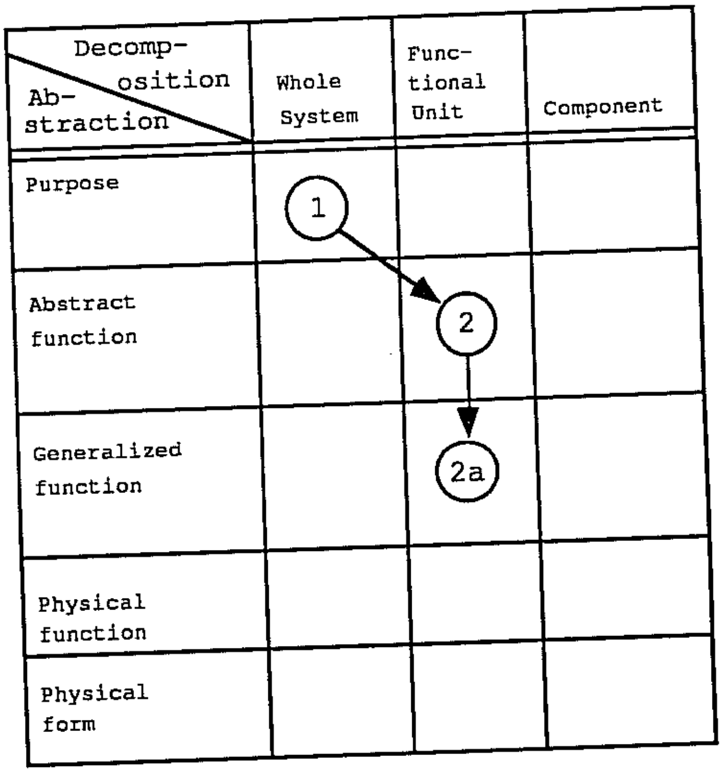

Figure 1: Diagram of steps followed in a typical design process.

Rasmussen uses diagrams to analyze the effectiveness of a design. Figure 1 shows how an interface designer works with different levels of a system, as well as at different levels of abstraction.

Turk has related these levels to Heidegger's modes of engagement (Heidegger 1962), in order to supply emotional aspects to cognitive modeling (see Turk 1990):

Level/mode 1 Theory (knowledge based or 'present-at-hand')
Level/mode 2 Principles (rule based or 'unready-to-hand')
Level/mode 3 Automated (skill based or 'ready-to-hand')

For example, when one uses a hammer, one is not conscious that the hammer is separate from oneself. (However, if one misses the nail and hits one's thumb, it is present-at-hand!) A computer's mouse can be viewed in the same way. Sarah Douglas questioned the second level, which is motivated by Rasmussen's schema, but not present in Heidegger. Gould suggested air traffic control as a GIS-related application area that has been studied extensively, and which is close enough to the domains studied by Rasmussen.

2.2.2. GOMS and Key-stroke Level Models

Douglas gave an introduction to GOMS and key-stroke level models.

GOMS is one of the predominant models resulting from HCI research. The acronym stands for <u>G</u>oals, <u>O</u>perators, <u>M</u>ethods, and <u>S</u>election rules. It has been applied to, among other domains, industrial engineering. Alan Newell did early work in this field and Card, Moran, and Newell (1983) is the original work on GOMS. In that book, a CAD/CAM system was analyzed. The methods work well for task analysis of skill-based behavior, but start to fall apart as the tasks are at higher, non-procedural levels. Newell was interested in mental activity during problem solving—a mental space formed by all perceived solutions. He started by studying puzzle spaces, then moved to more complicated examples.

Problem solving is finding a sequence of operators that accomplish a task. To do this, it may be necessary to use trial and error. There is a continuum between procedural and knowledge-based activities:

procedures <———> problem solving
routine <———> creativity
goals <———> goals
operators (certain) <———> operators (uncertain)
methods (sequences of operators) <———> selection rules (heuristics)

All human behavior can be said to be goal directed—therefore GOMS starts with goals. Establishing a goal is also important in being able to measure when a task has been completed. A GOMS analysis allows a task to be broken down into arbitrarily small pieces. Goals can be described as actions or as states to be achieved. In the end, the goals actually fall out, and sequences of operators are left.

To provide a concrete example, Douglas then applied the method to the task of displaying an image.

```
GOAL: Display an image
    Sub goal: select image from the group of available images
        Sub sub goal: Select a menu
            operator: locate menu, move cursor, click
        Sub sub goal: Select a specific file from a menu
            operator: locate file we want, move cursor, click
    Sub goal: view the image
```

GOMS does provide a way to look at particular, well-defined tasks. In particular, GOMS has been used to study text editing. It is important to note that GOMS does not (yet) work for the creative, problem solving stage. It assumes trained operators; the idea is to attach times to the operations, in order to optimize an interface for expert users. It is assumed that the operators are trained to the level that they make no mistakes.

GOMS implies a very detailed analysis and can be used at different levels of subdivision of a task. In practice, keystroke modeling is most often used. The keystroke model analyzes a task at the level of individual keystrokes (or comparable, small activities). It is a predictive model for the performance of highly trained users, achieving an explanation of between 80 and 85 % of observed behavior. It follows the tradition of MTM (motion time measurement) studies and is based on elementary, observable operators (or events) and measurements of the time they require:

Event	Time (seconds)
Keying	0.2
Pointing	1.4
Mental operation	1.8
Homing[1]	...
Drawing Line	...

The total time of interaction is equal to the human performance time plus the system response time, usually assumed to be instantaneous. As an example, consider a simple line-drawing task in a paint program:

select draw icon, draw line segment

mental operation
    pointing
    keying

mental operation
    pointing
    key press
    draw
    key release

GOMS works for *post hoc* analyses, not for design in the early stages. The method is based on an established subdivision of task, and identified scenarios. Different scenarios can be evaluated and the expected performance times can be compared, before actual implementations are done. It does not include error—but there are extensions. GOMS can be used to predict consistency of interfaces (with a production rule representation) and the transfer of knowledge between programs (e.g., text editors). It was mostly applied to text editors, but the results have rarely been used to design new editors. Market forces and users' aversion to change have limited the application of HCI results in this case, as in other cases.

The basic question is how much of GIS tasks are knowledge-based, and which are rule-based? GOMS applies best to tasks at the "skill" level. Mark points out that there may be value in these methods for routine GIS work, e.g., digitizing, which should not be ignored. Ellis reported on a different approach taken at Guelph. They work on design rationales based on Carroll's theory of task-artifact life cycles.

2.2.3. *Rasmussen's Theory*

Several participants felt that further clarification of the methods to analyze GIS tasks was needed. In particular, the considerable theories promoted by Rasmussen (Rasmussen and Jensen, 1974; Rasmussen, 1986) were mentioned. The group studied whether these theories could be applied to GIS task analysis, and tried to clarify the terminology used.

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[1] "Homing" is the HCI term for moving one's hand between a pointing device and the keyboard.

As an example, the group looked at the particular task of locating a new ambulance station (report by Turk). As input they assumed some data describing the past performance of established stations under a given call distribution. How can one reconcile a pattern of unacceptable response times?

First an attempt was made to understand the axes of the Rasmussen model in terms of GIS. Figure 2, below, clarifies the vertical axis of the previous diagram (Figure 1).

Term	GIS Use	Example
Purpose	Overall objective--reason for turning to GIS	Locating new ambulance station in optimal location
Abstract function	Main steps in resolving prolem (implicit)	Comparing existing regions with proposed new ones (with additional station) in terms of current and projected number of service deliveries
Generalized function	Parts of GIS functionality (i.e. software menu options) explicit	E.g. polygon join, overlay, buffer, cross--functionality would be content dependent.
Physical function	Execution of GIS functionality step	Acquire data set, repoly, mathematical comparison, choropleth maps, display
Physical form	How aspects of GIS functionality are physically held	Old and new data sets on disk, map on screen

Figure 2: Clarification of Vertical Axis of figure 1

Horizontal axis (of Figure 1):
- whole system: service system
- functional unit: service subsystem (e.g.,supply, demand, transport..)
- component: geographical primitives (nodes, links, attributes)

Vertical axis:
- purpose: overall function / reason for using GIS
- abstract function: main steps in resolving the problem (implicit)
- generalized function: parts of geographic functionality (as appearing in commands)
- physical function: execution of GIS operation
- physical form: how are data held (data storage)

A problem seems to be that there are too many different viewpoints in this taxonomy.

The results obtained from the discussion of this example were inconclusive. Rasmussen's abstraction levels seemed like arbitrary steps. HCI people would be interested in meta-design: What is the sequence of aspects that get analyzed? One seeming paradox was that "make a map of the response times" was just one step in the task breakdown, yet automated map-making was earlier thought of as too complicated to use as an example!

Given that there are other design methodologies, similar to Rasmussen's, which ones are best for GIS interface design? A possible next step for testing Rasmussen's methodology is to apply it to a problem where a solution is known, and see if the method reproduces an acceptable solution.

3. HOW DO PEOPLE THINK ABOUT SPACE

Mark opened the Monday morning session with a talk on spatial concepts and other cognitive science issues: How do people think about space, and how can user interfaces support these concepts?

A fundamental subdivision in spatial thinking is the conception of *space as fields* or space as a *collection of features*. A field is something that can be measured continuously varying over space, e.g., temperature or topographic elevation; it could be expressed as a function of position in space or space-time. Feature collections can be roads, lakes, cities, and islands, which are typical examples of geographic features; location may be included among their properties.

Our senses record our environments as fields of stimuli that excite the nerves of our sensory systems, but our sensory cortexes convert these sensory fields into features before they reach our consciousness. This is indicated by the fact that people describe space in terms of features. For most phenomena, fields are not really experienced as such; they represent abstractions. A similar process can happen in system use: even if a system is built entirely on a field concept, using images composed of pixels, users may interpret displays as if they are populated by features, a view which then cannot be easily and fully supported by the system. (For example, if a user asks "What is the area of this?", and clicks on what the user sees as a wetland, a raster-based system might respond in an unexpected or inappropriate way, such as by providing the area of a pixel.) The user observes then a discrepancy between his intentions related to features and the systems command language, which offers operations on fields.

In cartography and GIS, both fields and features in the world are modeled. A generalized view is Brian Berry's characterization of geographic observations as a geographic matrix of places (space), characteristics (theme), and time (Berry, 1964). In fact, this division of the world into space, time, and theme goes back to Kant and Newton (Blaut, 1961). David Sinton later related this directly to computer applications for geographic information by classifying situations according to which of space, time, and theme was fixed, which was controlled, and which was measured or observed (Sinton 1978)[1]. Multiple views of the same reality lead to multiple representations (Buttenfield and DeLotto 1989).

A special implementation-oriented model of space is the map layer. It carries over from manual cartography, the map library, and the light table. It was used metaphorically to organize early GIS and was theoretically analyzed by Dana Tomlin (Tomlin 1983, 1990). Michael Goodchild has described tessellations (or coverages) as special cases of fields, where the response variable is nominal (Frank and Goodchild 1990). Formally, the field and feature models can be seen as equivalent, and represent a duality perhaps similar to the particle and wave theories of electromagnetic energy in physics.

In the context of implemented GIS, there is the basic distinction between raster and vector data models (as well as data structures). Grid cells, rasters, or pixels are used to divide up space. In the Sinton model, time may be fixed, location controlled by the pixels, and theme observed or measured for each pixel. On the other hand, the vector model uses coordinates, lines, and polygons to describe geometry, either of spatial features or of

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[1] Apparently, the same schema, that of fixing one of space, time, and theme, controlling another, and observing the third, was presented by Deiter Steiner in a German-language article around 1972 (Tim Nyerges, personal communication, April 1992).

boundaries within a partition. Again time is usually fixed, but now theme is controlled, and the locations of features are observed. In general, raster models are often used to represent fields, while vector models are used for feature views.

How should these two data models be used in a GIS? In what terms do people think in the real world, with and without computers? Are there different schemata? Does the choice of data models make a difference for the user? Should the difference even show up at the interface level? Do people mix spatial concepts or switch between them? Are there cases where a bad decision was made as a result of the user's view and the system's view of the world being different? How does training affect spatial conception? Should we limit the discussion of spatial concepts to subjects with likely GIS backgrounds?

A feature can be different in different contexts. For example, to a traffic engineer a road is a link in a network; it has length, traffic volume, etc. However, to a conservationist studying turtle and frog migrations, the road is a barrier; to an electoral geographer or demographer it may be just another zone boundary, and to an urban child it may be an important play area. This context dependence has implications for the choice of data models. The crux is that GISs should whenever possible be developed to serve a multitude of user communities with different conceptions of spatial phenomena. Frank had observed that GISs based on a single spatial concept were easy to learn and to use but also were limited in functionality. GISs that included more than one spatial concept showed complex user interfaces and were considerably more difficult to learn.

3.1. Different users use different concepts (report by Tim Nyerges)

Features could also be called occurrences. An occurrence has location, magnitude, identity, and time associated with it. With two occurrences, distance, proximity, similarity, etc. are introduced. With more than a pair of occurrences, one gets a spatial distribution, with properties like density, pattern (independent of scale and boundary), and dispersion (spatial variance: clustering, uniformity, etc.). Finally, with many occurrences, concepts like regionalization, dominant and subordinate relationships, paths, etc., are introduced.

The medium through which spatial information is acquired influences performance of tasks. In way-finding, photographs or spoken directions may work better than maps, depending on the individual, the task, and the visual cues that are required. Each medium has a different wealth of cues, and novices sometimes need additional cues. When people are navigating, they want to know only where the decision points are and what they have to do at these points. Specifically, it has been found that many United Parcel Service drivers cannot work with maps, but do work well with a select set of still photographs. We do not understand how people use various forms of locational information—this requires human subject testing.

Education and training may affect what medium people prefer. Teaching map reading skills on a particular map should make this the preferred medium and other media are then less effective. For example, troops might not use image maps if they had not been trained in how to use them. On the other hand, United Parcel Service drivers might have maps as the preferred medium if they were given a map reading course.

Several phases of spatial information processing by humans have to be distinguished. What cues are relevant in each phase? Input, processing, and output of spatial information in a GIS should obviously be linked by common spatial concepts, but in practice this is not always achieved, as these correspond to entirely separated design phases. There is a difference in levels of geographic knowledge (landmark, route, and survey knowledge), which parallels the different general types of knowledge (procedural, declarative, configurational).

Image schemata (Johnson 1987; Mark 1989) are elementary spatial concepts that can be presupposed for any user population. They are expected to be 'universal' and not culturally dependent, and their semantics may be as precise as that of natural language (see Kuhn and Frank, 1991).

Do different user groups (professionals, normal population, special segments of population) require support for different concepts of space? Users must not only be differentiated by level of understanding or function in organization, but by concepts used, including cultural differences. Some modalities are better for some users (abilities, cognitive preferences). Distinguishing "special" and "normal" populations is not very precise; maybe different mental models would be a better approach. How can users be distinguished by mental models rather than by function, expertise, or abilities?

One useful tool is cognitive task analysis (see section 2). Cognitive tasks analysis attempts to model tasks by a hierarchy of increasingly complex cognitive activities. This hierarchy is different for experienced and inexperienced users. One cannot handle too many independent variables, but an experienced person stores mappings between variables. This requires an adaptive user interface, or selectable levels.

3.2. (Carto)Graphic output (report by Steve Smyth)

Modeling means chunking, simplifying, and abstracting from the external world as we experience it. Computers deal with limited models (discrete representations), which are often not in the preferred form of interaction. In fact, the representations are sometimes uninterpreted, as in remote sensing. What is the preferred mode of interaction? The naive answer is that the representation should resemble direct perception of the world. But this notion needs to be refined.

Consider intentional and deliberate distortions of output. Cartographers produce cartograms that specifically distort one aspect of space in order to communicate some variable or distribution. Generally, cartography distorts space in order to display it. Choosing appropriate distortions (not only in map projections) is a standard problem in cartography. Should inappropriate distortions be restricted in a GIS? If so, how? GIS should help to make displays flexible, provide anchors for easier interpretation, and reduce the amount of data in order to increase comprehension of what is shown. But there may be a clash between what is supported by the data and what the user wants to see.

A view of space as fields seems to be adopted whenever a feature view is unsuitable. Is it too abstract for a general user population (as opposed to geographers, soil scientists, foresters, etc.)? On the other hand, special populations like radio engineers think about fields all the time. The field/feature distinction has consequences for the perceived quality of data. Feature concepts tend to be understood as being more accurate than field concepts.

3.3. Congruence between internal and external structure (report by Jonathan Raper)

Can a user interface hide internal structures and in particular the spatial concepts that lie behind them? A "vote" among the group participants revealed that all but one felt that spatial concepts could indeed be hidden.

Specialized interfaces are not meaningful to the public—we need more generic concepts, but these are difficult to capture. Current interfaces describe geographic space and features mechanically—they do not persuade, but instead they must be 'read'. There is a need for persuasive means in interfaces, and in a sense, all representations are means for persuasion (Frysinger). We do not know very well how to draw attention, to make features persuasive—for example, how to convince politicians. Flashing and highlighting are very limited means and are often used in annoying ways. GIS often emphasizes concepts which are not features of the real world (points, lines, polygons, pixels etc.). Are the common 0, 1, 2-dimensional building blocks close to cognitive representations of space? How can we close the gap between these concepts and those which are more immediate to application specialists or politicians? Practically, a very disturbing issue is that professional (spatial) languages are not complete, and translations between different models are very difficult. They carry a cognitive load.

Three more deficiencies in current interfaces were discussed:

- the lack of a dynamic view,
- the weakness in representing fuzziness, and
- an unbalanced load across available sensory channels.

In the first case, there is a strong need to show processes. However, state-of-the-art GIS interfaces are generally not dynamic and consist of static pictures. How can a process be mapped to the interface? Secondly, we have difficulty representing fuzziness, the distortion caused by non-discrete atomic objects in the real world. How can we represent them as crisp concepts for administrative use? And thirdly, how can we exploit additional sensory channels? In a virtual reality situation, one might forget that one is using a GIS. To some extent, this already happens in games (for example, in SimCity), which are GIS-like in their functions, but are much easier to use.

On the other hand, GIS and cartography rely heavily on appropriate abstractions, which cannot always be perceived as such. So, what is reality for a GIS? Not necessarily the stuff "outside." What are the features that administrations and legal organizations deal with?

3.4. Levels of spatial cognition (report by Sarah Douglas)

Maps and GISs are systems that represent space, and are task related. The task determines which representation is appropriate. For example, wayfinding, data inventory, thematic or statistical visualization, and analysis of causal relations each may require a different representation of space and spatial phenomena. To recognize and accommodate the interconnections between tasks and representations is crucial for improved user interfaces.

One can differentiate various levels of spatial cognition, from the concrete to the abstract:

1. Pre-cognitive experience of space. Just being in the world.
2. Spatial relations. With the introduction of language and culture, our spatial sense is developed (here and there, near and far, etc.). These concepts are crucial for locating objects.
3. Mapping. Representation of the physical world may lead to a map, or another visual representation (although this depends on culture).
4. Thematic mapping. Geographic distributions of abstract features (e.g., population density).
5. Abstract 'spaces' represented in graphic spaces. Dimensional variables distributed by value in a spatial distribution (e.g., a three-dimensional visualization of corporate organizational structure such as those shown using the "Information Visualizer" of Card, Robertson, and Mackinlay, 1991).

All of these can be multi-modal, including sight, sound, motion, and tactile perception. They are also influenced by different perceptual and cognitive abilities and skills of the user. Some relevant cognitive abilities or skills include:

- detection, recognition and categorization of objects
- orientation of self or another entity in 2- or 3-dimensional space
- relative direction
- depth perception
- path finding by a sequence of landmarks
- movement of an object relative to a frame
- translation to 2-dimensional space

- mathematical manipulation of spatial relations

Clearly, there are individual differences with respect to these abilities and skills; it is less clear whether there also are differences that can be attributed to language and culture. If such cultural or linguistic influences can be documented, does it follow that they are also relevant for the design of GIS user interfaces? Elmes suggested that psychological studies of lacking or lost spatial abilities might provide valid background. Unfortunately, noted Golledge, much of that literature is wrong.

The design of any user interface requires an assessment of the kinds of abilities of the expected users, and either the adaptation of the system to the user, or the training of the user to use the system. Or both. We need to be aware of individual and cultural differences. The concept of a 'cognitive coprocessor', described by Card, Robertson, and Mackinlay (1991, p. 185), may be useful here.

4. INTERFACE STYLES AND PARADIGMS

New breakout groups were established Tuesday morning to discuss interface styles and paradigms. The WIMP (windows, icons, menus and pointing device) interface style has found wide application even in GIS software. Is this the optimal choice for the special requirements of GISs, and what alternatives must be explored? Obviously the choice of interface style and the corresponding paradigm are closely related to the available technology to build input and output devices.

4.1. Modalities: What channels for what tasks? (Shapiro)

Many interfaces are still designed around a command language paradigm (e.g., regular GRASS and ARC/INFO) but a host of alternative paradigms are available.

- WIMP (Windows, Icons, Menus, Pointing devices),
- Natural language (NL),
- Direct manipulation (DM),
- Dynamic querying with successive refinement (DQ), and
- Virtual reality (VR).

These paradigms are often more appropriately referred to as interface styles. An orthogonal classification would differentiate paradigms of system use as such, focusing on what users think they are doing rather than on how the interface looks and feels. Among these are:

- high-level programming,
- tool use,
- dialogue, and
- delegation to agents.

Some, if not most, interaction paradigms are metaphorical. A typical example is navigation. More on these distinctions can be found in Werner Kuhn's position paper for this meeting (this volume).

It is not clear *a priori* that one paradigm or style is superior to another, either in general or for a particular application or user group. Command languages are useful for experts, as they offer abbreviations for frequent operations. WIMP interfaces become complex when they go beyond single level menus. Direct manipulation has become very popular due to its intuitive appeal, but is sometimes lacking in expressive power. For example, selections of multiple objects based on attributes is often awkward or impossible to do in a direct manipulation interface. This represents, however, a frequent operation in GIS. It also seems questionable whether direct manipulation is appropriate for high-level operations, dealing with goals (knowledge level). Extensions to direct manipulations include visual languages like "Query by Example" (Zloof 1977), Programming by Example (PBE; Myers 1990), and iconic programming languages (Tsuda *et al.* 1990); Peterson and Kuhn (1991) have outlined the application of such a system to the definition of GIS data structures. The latter could transform a select set of GIS-related commands into icons, and provides visual tools to link those to sequences of actions.

Natural language is attractive when the interaction is conceived of as a discourse and includes gestures (which are an essential part of most natural language communication). It should be applicable, for example, to car navigation systems and to interfaces for casual GIS users. Dynamic querying means that a query remains on screen with attached "hot spots," linked to query results, which change when parts of the query are changed. The major advance brought about by virtual reality is the possibility of multi-modal feedback (e.g., tactile).

Paradigm and channel discussions generally deal with low level aspects of user interfaces. How can we treat high level concerns? How can we let the system take care of details, describing goals declaratively and processes only where necessary or desired? We need GIS languages that can abstract from the low level (i.e., implementation-required, not task-required) aspects. There is no language available for defining GIS tasks and reasoning about them. This may be the transition point between natural language or delegation paradigms and direct manipulation. CUBRICON (Neal *et al.*, 1989; Neal and Shapiro, 1991) is an attempt to leave low level operations to the system. Can we build interfaces using a 'query by example' style: give an example, extract pattern, and repeat it with some part changed?

For query and design languages, it would be beneficial to acknowledge and use different types of descriptions:

- by necessary and sufficient features
- by prototypes
- probabilistically (e.g., in remote sensing).

"Find all peninsulas in Massachusetts" is an example of a 'reasonable' query that may provide difficulties for many GISs. If we have the US Geological Surveys "Geographic Names Information System" files, with feature codes, we could simply search for peninsulas by code—if peninsula is one of the codes supported! (In fact, GNIS includes 'Cape', 'Point', 'Neck', and 'Hook', but not 'peninsula'.) So, how can we define 'peninsula' so that the system can search for them? And even if we have a database that includes a feature class called 'peninsula', how certain are we that the definition of 'peninsula' in that database matches the one we wish to use?

4.2. Technology (Ferreira)

4.2.1. Hardware

Hardware devices impose various constraints on interaction. The mouse has become a standard device. It is, however, inherently two dimensional. Although there are three-dimensional pointing devices ("flying" mice), it is said that they are unnatural and tiring to use.

Another issue is what type of device to give to novice users. Today's standard is a keyboard and a mouse (how many buttons?), but is this ideal? In the U.K., there are kiosks for tourist information. These kiosks have video disks, maps, and touch screen displays, and are simple enough to be used by most people. In informal observations, they appeared to be effective. Similar touch screen devices are now appearing in grocery stores in the U.S., and have been in use in hotel lobbies and in museums for some time (Gould *et al.* 1987).

Ultimately, interfaces will have more asynchronous, simultaneous input devices. They will be more like driving a car, where a user can be turning the wheel, pushing the accelerator, and looking in the mirror all at once. In order to achieve fast responses with real time interactive process control, parallel processing will be necessary.

4.2.2. *Virtual Reality*

With a workstation, the user looks at an image, but with VR the user is *in* the image. Not only can the data be viewed from multiple perspectives, but the physics of the virtual environment can also be controlled. For example, gravity can be adjusted (to make objects behave as relatively heavier or lighter than they appear) and the resulting effects can be observed.

One application for VR is data exploration. Because the user can be "inside" the data, it is possible to discern relationships that otherwise would be difficult to see. For instance, draping a SPOT image over a DEM would create a three-dimensional surface. The user could explore this surface by flying over it, perhaps using a pointing device similar to a flashlight to indicate areas of interest.

One drawback of current VR systems is the cumbersome hardware. Few if any users would want to spend eight hours a day strapped into eyephones, jumping around their offices. Today's VR systems do make sense in a military setting, where the hardware fits (or can be made to fit) into the environment. In general, what level of immersion, control, and connection is efficient and humane?

4.2.3. *Multimedia*

The real-time integration of multimedia data is an important research area. Birkbeck College has been developing a multimedia system (Rhind *et al.* 1988). One component of it was the Doomsday System, a multimedia "book" developed by the BBC to provide a look at the U.K. 900 years after the original "Doomsday Book." The system used two video disks containing pictures, sounds, and other information. One disk had an overview of the whole country, while the other detailed information about small areas. The user could navigate anywhere in the U.K. using the system.

The Doomsday System, combined with the GISTutor and HyperArc, was being shown to a group of planners. A planner would navigate to an area of interest, then HyperArc queries were executed to look at particular issues. Although this was a crude kind of integration, the effect was very powerful. Getting such a system going was a matter of choosing a small problem and figuring it out. The CUBRICON system, illustrated in the video that Shapiro showed earlier in the meeting, has several similarities.

United Parcel Systems has also worked with multimedia. They built a route planning system integrating picture and sound data. The system was used to communicate route plan information to drivers, using a series of pictures.

One problem with such a system is selecting information based on the experience of the user. A system has to know what the user knows and doesn't know. It is also important to know more about how people give other people information, for instance driving directions. When someone says, "the church on the left," what picture does the other person have in her mind? Another multimedia question is how to make sure that the user has enough information to stay oriented. For instance, with video fly by, the problem is how to let the user keep track of where he or she is on the display.

Feedback must be immediate in order to be convincing. This poses some particular problems for GIS applications, which are usually data intensive. Video disk, for example, is a very slow-access technology and the data can usually not be changed. The speed issue is currently limiting realistic Virtual Reality type systems to planning and other similar GIS applications.

4.2.4. *Time as a Mode*

An area of growing interest is looking at change over time. Studying temporal change with field data is very difficult, partly because temporal data are not always recorded. For example, the time that a road was built is not usually recorded. Also, because data are inherently multi-dimensional, it is difficult to tie in temporal information consistently—the data are not categorized in ways that lend themselves to scientific study. Finally, real time may be too slow or too fast to allow people to appreciate changes effectively.

4.2.5. *Summary*

In summary, computers have traditionally been command-driven black boxes. A user typed a command, the computer processed it and gave a limited amount of printed feedback. With the advent of Graphical User Interfaces (GUIs), it became possible to replace the black box with a "glass box." In fact, using object-oriented techniques it is possible to have the objects on the screen and the objects of a data model behave as one and the same. In this way, changes in the state of the system are readily apparent to the user. The user is automatically informed about transitions. The objects, and therefore the data model, can be manipulated directly, with feedback about the results being immediately available to the user.

The next step will be to "break the glass" of this glass box, as Tom Furness put it in his CHI '91 closing address: Virtual reality will transform users into participants. Through realistic and reactive simulations of geographic models, with multi-sensory feedback and direct involvement, a person might "vicariously" interact with the world, rather than with a more or less static model of it in a box, or worse, on a plane.

5. FUTURE GIS (DREAM SESSION)

In an attempt to free the participants from preconceived notions of what a GIS can or cannot do, the Monday evening session was designated as a "dream session," where six groups dreamed up potential computer support for geographic problem solving from a variety of perspectives:

- GIS issues for the operators (Leader: David Lanter)
- Intelligent, high-end GIS (Stuart Shapiro)
- GIS in the public / GIS appliances for the home (Mike Gould)
- CSCW: Computer-Supported Cooperative Work (Werner Kuhn)
- Virtual reality (Steve Smyth)
- Spreadsheet equivalent of GIS / integration with other systems (Steve Frysinger)

5.1. What are the GIS issues for the operators? (Lanter)

The operator is a spatial decision maker himself, working with some external source of information and requirements. Therefore, the operator needs tools for specifying or respecifying problems, for performing transformations between existing data and required results. As it is being used, the system must keep track of different trains of thought that the user is following in solving a particular problem.

A first useful function would be a *data brokerage*. It would know what data are on hand, what other users have, what the government has, including information about costs and availability. The data brokerage would understand what could be computed from available resources—in effect, deduce new features. A second tool would be a *method broker*. Other tools would express the logic for getting specific result data, including data of a specific quality, or format data in an appropriate way (format broker).

One impediment keeping us from such systems is that we generally do not (yet) have high-level methods to express our needs.

5.2. What is possible with an intelligent, high-end GIS? (Shapiro)

A high-end GIS is not necessarily intelligent. High tech is about improving the things that computers are good at, while an intelligent system would require little operator training.

Intelligent systems would be active systems. They would behave more like an advisor reacting to a proposal, checking the assumptions of, say, the planner. The system would be based on a trusted database, although advice need not be completely accurate. The GIS should itself be able to add to the accumulated knowledge of the discipline, by recognizing patterns and trends.

Working with an intelligent GIS would come closer to interacting with an intelligent person. These systems would have lots of data available and an integrated database with a unified access (may be distributed)—an important issue.

Redundancy will be a crucial feature of intelligent systems (sensitivity, multiple models, different levels of aggregation, redundancy as in human communication). Plausible reasoning, using short chains of probabilistic reasoning steps, would become possible.

Many of the improvements in computers seem to be filters to get data in the correct form, and tools for getting the right data. One useful additional input device/sensor combination would be a portable hologram projector and a gesture sensor. With them, another parallel visual channel could be used.

5.3. What is the future of GIS for the public, or the "GIS home appliance"? (Gould)

A GIS for the home would handle queries like, "Show me where Mark Twain was born," or "Tell me about my town's mall project," or "List the travel options for a vacation to England." The system would have information about public transportation, a library reference desk, driving directions, and travel planning.

Interaction would happen through home TV sets. Some services could be incorporated into existing systems, for example the MINITEL French video text system, or the early experimental TELIDON system in Canada. If virtual reality hardware were available in the home, as may soon be the case for video games, virtual reality vacation experience clips could be provided. At least Hypermedia, mixing spoken text, video, sound, maps, and printed text and tables, would be useful.

The possibility of such systems raised many questions. Would they be based on GIS or on hypermedia systems? Where would the data be kept? On a network? On CD-ROMs? Who would provide and maintain the data? What about issues of privacy and network junk? What will the user's role be in the system? Should political voting (or at least, public opinion polls) be linked to it? Will hardware cost remain a problem?

5.4. What can be done with Computer-Supported Cooperative Work? (Kuhn)

Computer-Supported Cooperative Work (CSCW) systems have applications wherever groups make decisions or otherwise interact and demand or supply information (see the proceedings of the ACM-sponsored conferences, CSCW'88 and CSCW'90). Examples would be GISs for Congress, for a community planning processes (e.g., for siting a waste facility), for high-level political decisions, or for corporate meetings.

Thus, the users would range from the general public to technocrats to managers and high-level government officials. They might be located in a common room or in their offices, spread across space (e.g., in different states or countries) or even across time (asynchronous "meetings"). Removing time and space constraints could be a fundamental contribution of such systems.

The system could have electronic agents take a role as a player (e.g., for a person who could not participate, or to represent regulations) or as a moderator and facilitator in discussions. Some roles in group processes might actually be taken over entirely by such agents. The system would allow more manageable brain storming and provide its users with instant documentation as well as feedback about problem solving states. It could also provide simultaneous translations.

Technological features could include very large screens, both public and private displays, and sketching devices and electronic post-its. The GIS would become a dynamic network, with varying participation of human and electronic agents.

Care would have to be taken to preserve features which people rely on in group processes. Among them are the wide variety of communication channels (e.g., eye contact, observing uncontrolled muscular and other bodily reactions) or the ability to "show off." On the other hand, inappropriate solutions (e.g., skin response sensors) could lead to privacy invasion problems.

CSCW research has also revealed that an exposure of a whole decision process is not always desirable (see the work of Jonathan Grudin). People may fear a big-brother like documentation of responsibility and authorship, as well as an uncontrollable change of power structures. This is an instance of a general problem with information technology: the undesired elimination of their imperfections. There is also a questionable underlying assumption that information plays an important role in decision making.

Still, supporting group decision making and cooperation seems to be one of the things that is close to the core of what GIS is really all about. The expectations are out there, and some success stories have already been reported (e.g., for school planning). Additional benefits could be derived from powerful simulation capabilities for research and training purposes.

5.5. What can be done with virtual reality? (Smyth)

Virtual reality (VR) allows for a seductive interface. It provides a direct coupling of visual and tactile processes with human movement (proprioceptors) and a virtual world, creating a powerful medium for communication.

One application is exploring data. One can overlay various kinds of data, then actually move through the space they occupy. One could actually experience different viewsheds, or manipulate multivariate data with a data glove, with each joint connected to one variable.

5.6. What is the spreadsheet equivalent of GIS / Where does system integration lead? (Frysinger)

The key to a spreadsheet is dynamic updates of data while work is in progress. To that end, an implementation dream might be GRASS tied to a spreadsheet by some dynamic functional relationship, where multiple representations would be linked by "hot links." GIS overlays could then involve dynamic updates. Geographic Data Technologies, a company in New Hampshire (USA) markets a system called "Geo Spread Sheet" that has some of these characteristics, primarily designed for political re-districting tasks; ESRI's ArcView also links spread sheets and maps.

Appropriate system integration should primarily provide better access to data, with operations that work on these data independently. GIS might thereby become more of a data switchboard than a database (taking up the brokerage idea).

6. PARTICULAR PROBLEMS

The Tuesday evening session was devoted to particular problems that have surfaced, but were not given sufficient time for discussion. They revolved around the currently available technology and its limitations—and thus contrasted with the previous day's 'dreams'.

6.1. What experience is there with tools for design and rapid prototyping? (Elmes)

When discussing user interface design tools, it is useful to discuss four stages of design: conceptual, semantic, syntactic, and lexical. The conceptual level deals with the choice of metaphor(s) and of the objects of discourse, the semantic level with the meaning of operations, the syntactic with expressing those operations, and the lexical with the physical activities necessary to perform the operations. Today's design tools work mostly at the lexical and syntactic level, with few tools but some methods at the semantic level, and neither tools nor methods at the conceptual level. One way to get more powerful tools would be to enhance existing tools, like NextStep, to include higher levels of functionality, which would allow designers to specify GIS semantics.

To design advanced user interfaces, such as for GIS, tools are needed that work at the semantic level. These might take the form of general purpose specification languages, e.g., MIT's LARCH, which is a tool for algebraic specifications (Guttag, Horning, and Wing 1985). The current methods that exist for user interface design do not anticipate problems—some of them as simple as identifying the routine in a given library of interface techniques that performs the desired function. Thus, better browsing techniques are needed to support interface designers. Multi-modal interfaces are not only promising for GIS themselves, but for systems to design GIS, where the domain is communication rather than geography (Shapiro).

An important question for our community is whether there are unique conceptual and semantic properties of GIS operations. Today's GIS interface requirements may not be so much different from other spatial domains, such as CAD/CAM (Elmes). If GIS needs are special, however, then there is a need for object-oriented libraries with GIS functionality and possibly even for GIS-specific widget sets (Cumpston).

A hopeful note is that integration of tools is becoming standard—OpenLook, Motif and X-windows are commonly being nested and combined. Generic tools will help to connect diverse applications with a common look and feel. One such tool, Open Interface from Neuron Data (Palo Alto, California), works with Macintosh OS, Motif, OpenWindows, and Presentation Manager. It was used in designing ArcView, the new product for viewing ARC/INFO databases.

6.2. Obstructed Channels (Lupien)

For various reasons (handicaps, technological constraints, economics), it may not always be possible to use the optimal or intuitively appropriate channels for communication in GIS user interfaces. This group discussed the needs of special populations (e.g., visually impaired) as well as problems of interacting with a GIS in a sparse channel situation, such as over a telephone.

6.2.1. Telephone-Based GIS

Telephone-based GIS or GIS-like systems are not a new concept. A telephone-based system for giving driving directions was developed years ago at the MIT Media Lab by Chris Schmandt, Jim Davis, and their colleagues; Digital Yellow Pages are becoming a reality. Cellular phone users in New York can dial *JAM to get information on alternate routes during traffic jams. In these systems, the telephone can be thought of as a terminal. It has keypad (including letters) and voice input channels, voice and the ringing bell as output channels. A telephone can also support fax machines and thereby static graphical input and output. Telephone terminals can be located almost anywhere in the world. In many areas of the United States with "911" emergency services, fixed telephones have precisely known locations. Cellular phones can be located roughly by cell station, or could use GPS receivers for precise positioning.

6.2.2 Real Time Navigation Systems for Blind Travelers

In order to navigate, one must have or obtain information about current location, orientation, proximal links or landmarks, bearing, distance, priming (for the next landmark), and choice points. Sighted people usually navigate using visual reference points, often subconsciously. A blind traveler must be enabled to sense the reference beacons by some other means—e.g., auditive or tactile.

One way to allow non-visual navigation is to borrow technology from virtual reality, and build a virtual sound space. In such a space, location and pitch can be used to give the traveler a sense of the environment. Buildings, and other items of interest, could actually "call out" to the traveler. Pay phones could then act as help stations, giving position information or providing location-specific data. Primitive examples of this type exist already in public spaces (airports, etc.). But a danger of using sound VR in navigation is that sound is a critical channel for information about features and hazards of the real world. Further research is needed to test people's abilities to move through sound spaces and use some kind of maps of them. Golledge is envisioning a laptop-based system that uses region-specific data. The system would be used by both visually impaired and sighted people. The interface does not use cartographic maps at all, but auditory and tactile information about the immediate environment.

The discussion turned into a design session for an entire system, departing from user interface concerns. It provided a good example of the primacy of user interface issues in overall system design.

6.3. How do query languages relate to interface issues? (Smith)

There are some general issues that must be considered. What do users want from a system? What information can they be expected to know? What information will they be required to know before using the system? Should a system replicate human skills or complement them? What are the specific requirements of a given application area? Is there a core family of deep languages (based on logic)? How can radial categories and prototypes be reconciled with the classical, feature-based paradigms of SQL ("Standard Query Language") and other query languages? Answers to these questions will have an impact on query language design. Opinions about query languages are as varied as the people discussing them. On the other hand, the GIS community does not have a rich set of query languages which are able to describe objects, locations, functions, and relations between objects

What are the typical queries? In administrative settings, 90% of queries are standard queries, but this is not the case for scientific databases or exploratory planning and design tasks. Applications that use a field-based geometric model (e.g., remote sensing) define problems in terms of locations and interrelationships of locations. However, there must also be a representation involving objects and their interrelationships. Concepts like shading, time, and appearance of objects have to be considered. This interaction between field-based and feature-based concepts underlies many issues in query languages.

With a feature-based model, other problems arise. Fuzziness of objects, or object edges must somehow be modeled. This can be partially solved by determining the user's purpose. Fuzziness can also be dealt with using natural language ("it is about 3 or 4 miles north of the freeway"), but this cannot yet be handled easily by formal systems.

Another important research area is building a foundation for dealing with fuzzy geometry. How do people deal with imprecise objects and geometry? From the user's perspective, there may be fuzziness in their understanding of the problem, and therefore they may not be able to formalize a query precisely. Logic based interaction languages may serve professionals, but not the public at large.

Will we need different query languages for different settings? For different scales? In general, do different kinds of spaces (everyday, manipulable object spaces; indoor transperceptual spaces[1]; geographic spaces) require different query languages? How can cultural differences best be accommodated? Core concepts that are culturally independent must be identified (if they exist). There is ongoing research into whether or not different spaces have formally different geometries. Can one combine different spaces in one query? For example: "find the building in this city with a room with a table with a spoon in a cup."

6.4. What are specific user interface problems with current GIS? (Potter)

6.4.1. Basic Features.

Existing GISs have problems not unlike the problems that other software products had 10 to 20 years ago. Upgrades can be inconsistent, and different parts of a system are sometimes not well correlated. Basic file management is often awkward. For instance, in one system, files cannot be replaced by other files, while in another, the system must be restarted if a valid filename is not supplied. Editing features now common in word processing software, such as an "undo" command, are lacking in many GIS situations. Some systems require excessive switching between mouse and keyboards. Error messages are often uninformative, an extreme being a system which simply stated "bailing out," and quit the current process. One system had a conflict between the representation of an object for graphic output, and its representation for analysis.

6.4.2. Advanced Features.

Beyond the basic features, GIS user interfaces also exhibit problems. They often suffer from poor macro language facilities, making the automation of repetitious tasks too difficult. There are many instances where effective expert advice could be offered, for instance in color selection.

6.4.3. Technical Issues.

There are a number of technical issues regarding underlying hardware and software components that have a direct effect on the user interface. These are often thought of as spatial database issues, but they have a major impact at the user interface level. Perhaps the most obvious issue is response time. Certain tasks with GIS take an extraordinarily long time, on the order of minutes or even hours, whereas HCI principles suggest that a maximum response time of two seconds is needed for natural interactive computing. Another issue is working with multiple files, and multiple users accessing a single file.

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[1] 'Transperceptual' is a word used to describe a space that cannot all be perceived from a single viewpoint, but rather must be 'assembled' in the mind from separate perceptual experiences. To the best of our knowledge, the term was introduced by Downs and Stea (1973).

6.4.4. Learning New Systems.

GISs are generally very difficult to learn. This difficulty is not simply removable by switching from a command line to a WIMP paradigm. For example, although OSU MAP has a command line system with many non-intuitive commands, it is easy to teach most students how to use it. It is not clear whether training times will decrease with object-oriented designs. Furthermore, it is not clear whether there are genuinely GIS-related interface difficulties or whether these are just left-over general computing difficulties.

7. THE RESEARCH AGENDA[1]

To set the research agenda for the topic, five working groups were formed on the last day of the meeting, to compile lists of researchable questions in five topical areas which had emerged during the meeting. We termed the five areas:

- Task Analysis and Taxonomies
- Testing and Experimental Design
- Spatial Concepts
- Interface Metaphors
- Issues for Decision Makers

The following sections describe specific researchable topics or key issues under each of these areas.

7.1. Task Analysis and Taxonomies

The overall objective in this area is to develop a framework for analyzing and comparing GIS interfaces by developing one or more taxonomies of GIS uses and associated task decompositions into component user tasks. This effort must be sensitive to different types of users. Specific questions to be addressed include:

- What taxonomies of tasks are needed?
- What are the critical dimensions for classification (user expertise, types of tasks, application areas, etc.)?
- How can task taxonomies be reconciled with GIS use situations?
- How can individual differences be accommodated?

These issues need to be pursued via the development of GIS task and user taxonomies, to be tested with different types of task analysis procedure. An understanding of which procedures are most effective, and how task analysis may be used in GIS design, will be facilitated by the development of an integrated theory-based reference model of the cognitive aspects of user-GIS interaction (Turk 1990).

7.2. Testing and Experimental Design

The need for testing and experimental work arises from:

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[1] This section of the report was previously published in the Proceedings of the ASPRS/ACSM Spring 1992 meeting. See Mark *et al.*, 1992.

- the desire to validate assumptions about how spatial concepts, behavior, and capabilities of users interact with system use,
- the need to compare systems and components, and
- the goal to match user interfaces to users' mental models.

Testing should provide an objective basis for assessing the quality and effectiveness of user interfaces, including the conceptualization of the user interaction with their work, and the effects of various choices of interaction devices on task performance (Freundschuh and Gould, 1991).

Many experimental methods are available in the literature (see several of the papers in Helander, 1988). Experimental design skills are valuable, learnable, and transferable. Experimental methods can be applied at several levels of system integration: whole systems, subsystems (maybe cognitive setting is operating at this level) and at atomistic levels (to test small aspects like interaction device, color choice, icon design, button placement, etc.). One important research project would be to measure the fit between systems and users within a task context; i.e., testing complete systems in context;

A reference framework should relate cognitive issues to the symbolisms, the devices, and the perceptual/motor level. Thus, it should provide a continuum from high level to lower level skills.

Three specific projects were deemed to be of value:

- A review article on existing experimental methods applicable to characterize user interfaces, relating them to the types of questions they can answer and giving examples of their application. The article should probably include a chart similar to the charts of what statistical methods to use in the end pieces of books such as Blalock's (1960) "Social Statistics" or Siegel's (1956) "Non-Parametric Statistics".
- User interface specifications for various applications that might be applied by designers.
- User interface benchmarks for various applications, particularly a set of benchmark tasks.

7.3. Spatial Concepts

It seems obvious that the concepts that appear in the user interface of a computer system must match the user's conceptual model of the phenomena under consideration, if the computer system is to provide a usable model of the world. This is often achieved by the user modifying his or her conceptual model through training or experience with the system. But the more closely the system's design approximates the user's view of either the system or the phenomena represented in the system, the easier the system will be to use. Thus a comprehensive review of the spatial concepts that underlie GIS-related tasks and other things that people might do with geographic software, must be viewed as a prerequisite to user interface evaluation and improvement. Frank and Mark (1991) have reviewed some of the links between language, spatial cognition, and GIS.

Specifically, there is a need for a reference framework that relates cognitive issues to the representations of space that are evident in the interface. Additional research issues revolve around the following points:

- A common sense understanding of space needs to be distinguished from the spatial concepts of various professions (e.g., lawyers versus planners). Are there any universals in these, e.g., image schemata (Mark, 1989)?

- How important are cultural differences for dealing with spatial relations at the user interface?
- Spatial concepts could be expressed more effectively if a variety of output modes (graphics, text, speech, other sounds, etc.) were available. For example, graphical output requires over-specification of geometry; if we know only topology, we could communicate that more honestly to the user through verbal output than through a picture.
- Is natural language a suitable interaction medium for spatial problems? If so, how can gestures be integrated?
- How declarative can a query language be?
- Are specific choices of spatial concepts and logics sufficient for a given application area?
- An "anthropology" of different GIS cultures (e.g., ARC/INFO vs. Intergraph) might reveal interesting insights into universal and system-specific conceptions.
- How can the idea of a spatial syntax be used for organizing spatial knowledge?
- Wayfinding was found to be a suitable task for observation.

7.4. Interface Metaphors

Research on interface metaphors is motivated by both GIS-specific and general HCI concerns (Gould and McGranaghan, 1990; Jackson, 1990). Among the participants, there was widespread agreement that we need to go beyond map metaphors in order to take full advantage of dynamic system capabilities. The field of HCI, on the other hand, is looking for interesting application domains where theories of interface metaphors (among others) can be applied and operationalized in actual interface designs. Therefore, the following list contains both GIS-specific and general HCI research questions on the role of metaphors in user interfaces.

- What makes a good interface metaphor good? (Find theoretical and experimental evaluation methods, analyze successful cases like the desktop or map metaphors)
- How can metaphor candidates be generated? Possible sources include: artifacts and tools used; domain languages found in documentation, regulations etc.; domain symbology; existing models; and video games
- Which generic metaphors (e.g., toolbox, desktop) are appropriate for GIS?
- What is the role of metaphors in task analysis?
- How can metaphors be integrated into a conceptual design? Can metaphors be designed to be adaptable, or even customizable?
- Does the choice of metaphors affect the syntax of interaction languages?
- What is the connection between metaphor choice and the use of a User Interface Management Systems (UIMS)?
- How can metaphors be coherently combined and nested?
- How can metaphors be communicated to users?
- What is the role of visualization for metaphors? (Image-schemata by definition have associated images.)

- How can appropriate multi-modal expressions of metaphors (combining image and sound, etc.; see Mountford and Gaver, 1990) be found?
- When is "magic" (i.e., violating a metaphor) appropriate?
- How do work space and geographic space interact (e.g., meaning of up/down on screens)?
- What are the image schemata and metaphors behind features, fields, and other concepts of space?
- Can we optimize GIS metaphors with respect to cultural invariance? Or should we exploit culturally-relative metaphors when appropriate?
- What are appropriate metaphors for interaction with three-dimensional and time-related spatial information?
- What are appropriate metaphors for Computer Supported Cooperative Work (CSCW) in Spatial Decision Support Systems (SDSSs)?
- What agent paradigms are suitable for GIS (map maker, surveyor, analyst, model maker, etc.)?
- Could there be metaphor-free GIS interfaces? If so, where and how is this possible?

7.5. Issues for Decision Makers

Decision makers, for example professionals represented in URISA or AM/FM International, have specific needs to be satisfied by a GIS that are different from those of, say, a scientist. What differences in the user interface are appropriate?

First, decision makers are particularly sensitive to the level of confidence they can have in spatial data products. Research into means to inspire confidence is necessary, and some is already underway in the NCGIA's Initiative 7, "Visualizing the Quality of Spatial Information" (Beard and Buttenfield, 1991). Two of these are:

- to show 'correct' data whenever possible; and
- to get the users to understand an analysis, including limitations.

Confidence is often achieved through anecdotal evidence rather than exhaustive tests. How can this fact be usefully applied to interface design?

Second, the usability of software is essential to decision makers. They need special forms of data access, special forms of products, information on what a product represents, and safeguards against violating elementary cartographic principles in presentations.

Third, decision makers will increasingly work in distributed decentralized computing environments. This requires again appropriate access methods (e.g., browsing and intuitive query languages), the possibility to backtrack along trails of evidence, and provision of intelligent error notifications back to data producers.

Finally, Computer Supported Cooperative Work (CSCW) is likely to play an important role in future decision making processes, including SDSS. Building prototype models (e.g., of town infrastructure) from spatial data is an effective means of decision support.

7.6. Comparing Research Agendas

It is interesting to compare the Initiative 13 research agenda with the more general agenda for human-computer interaction (HCI) recently described by Marchionini and Sibert (1991). That agenda resulted from a workshop held at George Washington University (GWU), March 4-5 1991, and attended by 22 authorities from the HCI community. (There was no overlap in participants between the NCGIA meetings and the GWU workshop, and Marchionini and Sibert's paper did not appear until late 1991; however, several participants at the I-13 meeting were students of participants in the GWU meeting.) Marchionini and Sibert (1991, p. 17) identified four broad areas of concern:

- HCI Models
- Input/Output Devices and Interaction Styles
- Software Tools and Architectures
- Computer Supported Collaborative Work (CSCW)

Recall that the NCGIA specialist meeting developed a research agenda under the following five headings:

- Task Analysis and Taxonomies
- Testing and Experimental Design
- Spatial Concepts
- Interface Metaphors
- Issues for Decision Makers

How are these two sets of bullets related? "Task Analysis and Taxonomies" proposes research that would apply "HCI Models" to geographic problem-solving and GIS. Our category of "Testing and Experimental Design" would seem to be primarily focused on the practical evaluation of "I/O Devices and Interaction Styles", although hardware issues were barely mentioned in the discussions at the NCGIA meeting. Our "Interface Metaphors" would also seem to fall under this bullet, but represents a more theoretical or conceptual side of the issues. The remaining two components of our agenda, namely "Spatial Concepts" and "Issues for Decision Makers", address theoretical and practical issues, respectively, in the specific areas to which GIS is applied; domain-specific issues were not explicitly addressed by Marchionini and Sibert. Conversely, of the last two major categories of Marchionini and Sibert's (1991) agenda, "Computer Supported Collaborative Work" was mentioned briefly under our heading "Issues for Decision Makers". "Software Tools and Architectures" was not highlighted in the research agenda of our meeting, but were frequently mentioned in our discussions. These will probably become more important in the UIGIS agenda, especially in Westervelt's (1990) idea of two kinds of users: end users and 'customizers'. Customizing the user interface will be much easier if the generic GIS supplied by the vendor has a good User Interface Management System (UIMS).

8. ELECTRONIC DISSEMINATION OF INFORMATION: UIGIS-L

In order to foster communication and interaction about these issues, we have established a BITNET Listserver called UIGIS-L on UBVM, an IBM mainframe at the University at Buffalo. Messages sent to this listserver at UIGIS-L@ubvm.cc.buffalo.edu [Internet], or simply to UIGIS-L@UBVM [BITNET] are distributed to members of an open subscription list. There is also a limited distribution of this information on Usenet (Netnews) as bit.listserv.uigis-l. If you have electronic mail access yet either cannot subscribe to bit.listserv.uigis-l, or prefer to receive UIGIS-L material as electronic mail, then send a 1-line subscription message to:

LISTSERV@UBVM.cc.buffalo.edu [Internet] or

LISTSERV@UBVM [BITNET]

and the one-line message should be:

SUB UIGIS-L 'Your name'

You will then receive any items sent to UIGIS-L. You can also post messages or questions to UIGIS-L without being a subscriber.

As of 24 April 1992, a total of 209 items had been posted to UIGIS-L (0.7 per day), with 63 people posting at least one message each. Of those, the 14 who were specialist meeting participants posted 101 items (48 percent). Twelve other people who did not attend the specialist meeting posted 3 or more messages; of these people active on UIGIS-L, 3 had been invited to attend the Specialist Meeting, but were unable to attend for personal or other scheduling reasons.

As of 24 April 1992, UIGIS-L had 237 subscribers from 24 countries. A breakdown by region (see Table 1) shows a preponderance of subscribers from English-speaking countries, much more so than on GIS-L, a more general-purpose GIS discussion list.

Table 1: UIGIS-L Subscribers by Region and Country

United States	147
Other predominantly-English-speaking Countries	45
(Australia [13], Canada [16], Ireland [1], New Zealand [2], United Kingdom [14])	
Other European Countries	35
(Austria [5], Belgium [1], Czechoslovakia [1], Denmark [1], France [1],	
Germany [3], Greece [1], Italy [5], Netherlands [5], Norway [2], Poland [2],	
Spain [4], Sweden [1], Turkey [3])	35
South America (Brazil [3], Colombia, [2])	5
Asia (Saudi Arabia [3], Singapore [2])	5
Total	237

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User Interfaces for Geographic Information Systems

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