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Formal Models of Commonsense Geographic Worlds: Report on the Specialist Meeting of Research Initiative 21 (97-2)

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Report on the Specialist Meeting of Research Initiative 21

Discussions at the Specialist Meeting

October 30-November 3, 1996

San Marcos, Texas

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1. Executive Summary

This report describes the outcome of the Specialist Meeting of the National Center for Geographic Information and Analysis (NCGIA) Research Initiative 21 on "Formal Models of Commonsense Geographic Worlds." The meeting was held in San Marcos, TX on October 30 - November 3, 1996

Research Initiative 21 is concerned with the development of formal models of commonsense geographic worlds. Discussions at the Specialist Meeting focused on the commonsense or *naive* geographic reasoning that people perform and whose outcome makes intuitive sense to most people. The Specialist Meeting brought together specialists from geographic information science, artificial intelligence, computer science, geography, developmental psychology, and behavioral science to foster discussions leading towards a better understanding of the nature of naive geographic reasoning and how better to incorporate naive geographic knowledge and reasoning into geographic information systems (GISs).

This Research Initiative is related to previous research activities of the NCGIA, especially, "Languages of Spatial Relations" (Research Initiative 2) (Mark *et al.* 1989; Mark and Frank 1991) ,"Spatio-Temporal Reasoning in GIS" (Research Initiative 10) (Egenhofer and Golledge 1994) , and "User Interfaces for GIS" (Research Initiative 13) (Mark and Frank 1992) . The Research Initiative on *Commonsense Geographic Worlds* differs from these earlier Initiatives in having a much stronger emphasis on principles from Artificial Intelligence.

The Report on the Specialist Meeting serves to document the discussions held during the meeting and, most importantly, delivers a set of researchable questions that forms the basis for future research in this area. Participants collected close to 50 questions worthy of further consideration and research on topics relating to the fundamentals of Naive Geography, developmental influences on Naive Geography, and the impact of Naive Geography on GIS.

2. Acknowledgments

Development of the ideas leading up to the meeting benefited greatly from discussions with Geoff Edwards, Andrew Frank, Pat Hayes, Dan Montello, and Barry Smith. The meeting was supported by the NCGIA's grant from the National Science Foundation, grant number SBE-8810917. The European Science Foundation's GISDATA Project and the European Union's SPACENET group were co-sponsors for European participants. Dr. F. Benjamin Zhan from the Department of Geography and Regional Planning, Southwest Texas State University (SWTSU) made most of the local arrangements for the meeting. Dr. Lawrence Estaville, Chair of the SWTSU Department of Geography and Regional Planning, also provided support for the meeting. Some SWTSU students were especially helpful, driving shuttle vans between San Antonio airport and San Marcos, and between the hotel and the campus. The facilities in the library at SWTSU contributed substantially to the ambiance and productivity of the meeting. Kathleen Hornsby, Steven Parkansky, Martin Raubal, Trudy Suchan, and Leo Zaibert acted as rapporteurs and assistants during the workshop. Pat Shyhalla, Diane Holfelner, and Dawn Becker of the NCGIA office in Buffalo assisted with arrangements and expense reimbursements for the meeting. The help of all of these people and organizations is gratefully acknowledged.

3. Introduction

Early in 1996, the National Center for Geographic Information and Analysis formally approved a new research initiative entitled "Formal Models of Commonsense Geographic Worlds." This became Research Initiative 21 of the NCGIA, with David Mark (NCGIA-Buffalo) and Max Egenhofer (NCGIA-Maine) as the Initiative co-Leaders. We propose that formal models of commonsense geography, also known as *Naive Geography* (Egenhofer and Mark 1995) , are a necessary prerequisite to the development of geographic information systems that are truly intuitive and easy to use. The objectives of the research initiative were stated as:

- Identify basic elements of commonsense conceptualizations of geographic space, entities, and processes, and develop an integrating framework.
- Investigate GIS users' reactions to intuitive geographic inferences and compare the inferences with the results obtained with current GIS technology.

Naive Geography is seen as the body of knowledge that people have about the surrounding geographic world (Egenhofer and Mark 1995) . More specifically, the core concepts for intuitive GIS will be those that make up a primary theory of geographic space, entities, and processes. Primary theory (Horton 1982) covers knowledge for which commonsense notions and scientific theories correspond, and furthermore, these notions should be, if not cultural universals, at least wide spread across many cultures.

Formal models of the entities, relations, and processes to be represented in the program must be developed so that software that behave consistently and correctly can be written. When computer programs are developed without explicit and careful formal model development, consistent program execution is unlikely. Although many computer programs have of course been written based on *ad hoc* principles, these are very likely to present problems, if not initially, then when they need to be updated, expanded, or extended to new situations.

Formal models of commonsense knowledge have been examined by philosophers (Smith 1996; Smith 1997) , and commonsense physics, or naive physics, has been an important topic in artificial intelligence for some time (Hayes 1978; Hayes 1985b; Hayes 1985a) .

Delivery of sophisticated technology to the general public is becoming a reality through interactive cable television, Internet access, and CD-based software for home computers. Software with GIS functionality that can be used given only commonsense knowledge of geography would be very helpful in delivering spatial information to the public. Formalizations of commonsense geographic concepts are necessary underpinnings for the design of GISs that can be used with little or no training by new user communities such scientists, or the general public.

In order to advance research on this important topic, the NCGIA organized a 3-day Specialist Meeting, a workshop intended to refine the topic and identify researchable questions. A Call for Participants was prepared in April 1996 and distributed by electronic means, as well as published in newsletters of geographic and psychological societies. An international Steering Committee assisted the Initiative leaders in selecting participants and developing the program for the meeting. These were: Roger Downs (Pennsylvania State University); Andrew Frank (Technical University of Vienna, Austria); Janice Glasgow (Queens University, Canada); Patrick Hayes (University of Western Florida); Daniel Montello (UC Santa Barbara); Barry Smith (University at Buffalo); and Barbara Tversky (Stanford University).

Some 45 people submitted proposals to participate in the meeting; each proposal was reviewed by seven of the nine Steering Committee members (including the co-Leaders) and mean summary ratings were a major guide to decisions on whom to invite. Of the "at large" applications, 25 people were invited to attend the meeting. Other participants included the Steering Committee members, and four invited guests.

The remainder of this report reviews the content of the meeting in chronological order. It is hoped that readers of this report will get a feel for the discussions and findings of the meeting. More details and updates about this initiative's activities may be found through its Web page at http://www.geog.buffalo.edu/ncgia/i21/.

4. Welcome and Self-Introductions by Participants

David Mark and Max Egenhofer opened the Specialist Meeting and welcomed researchers from seven countries and twelve US states. Lawrence Estaville, chair of the Department of Geography at SWTSU, also gave a warm welcome to the group. The workshop began with a session in which the goals of the meeting and the participants were introduced. After the introductions, David Mark and Max Egenhofer talked about the history of NCGIA Specialist Meetings and research initiatives. Research initiatives focus on special topics and include people from the academic research community, vendors, and government agencies. The main goal is the identification of a research agenda for the topic.

This Initiative will focus on the cognitive aspects of geographic space and computational methods and models of geographic concepts as well as the design of systems that integrate the ideas of Naive Geography. One product of the meeting is this technical report, which summarizes discussions and puts the established research agenda into print. Another outcome of this meeting is short term and long term research goals in the form of researchable questions. These should be specific, having the granularity of a Master's or Ph.D. thesis, therefore, also functioning as a resource for the student and advisor community. The outcome of the meeting should stimulate research in Naive Geography through future meetings, publication of papers, and dissemination of research results.

David Mark spoke briefly about the history of NCGIA research on areas related to Naive Geography. A meeting was held in Buffalo in 1988 on cognitive and linguistic aspects of geographic space. This was followed by the NCGIA Initiative 2 Specialist Meeting in Santa Barbara in 1989. In 1990, there was a meeting on Cognitive and Linguistic Aspects of Geographic Space in Las Navas del Marqués (Spain), which resulted in a book published by Kluwer (Mark and Frank 1991) . The COSIT (Conference on Spatial Information Theory) conferences, held biannually (Frank and Campari 1993; Frank and Kuhn 1995) , are another important activity that contributes to the development of this body of work.

5. Common Sense Spatial Reasoning

To put the topic of the workshop in the context of some of the research areas from which we hope to draw theories and concepts, the first session of the workshop was a panel on three perspectives of common sense. Subsequently, a plenary group discussion attempted to discuss the different views and link them to the Initiative's agenda.

5.1 Ben Kuipers' Perspective

Ben Kuipers gave a presentation on commonsense knowledge and its importance in Artificial Intelligence (AI). Commonsense knowledge provides the background for all other knowledge; it is "mysteriously robust to errors and failures," integrates incomplete knowledge, and uses simple models. Furthermore, linguistic metaphors appear to be grounded in commonsense knowledge.

Kuipers explained the different research strategies followed in earlier work by McCarthy, Lenat, and Hayes. He went on to describe why spatial knowledge is a critical problem for AI. There is an important gap between continuous reality (space, time) and the discrete symbolic models that are used in AI. One question is how symbols are grounded in experience, that is, sensori-motor interaction with the world. Kuipers also observed that the cognitive map is an especially accessible feature of human cognition, and is thus easier to study than other cognitive processes. Different people have different cognitive maps, which raises the additional important question how communication can taking place.

There are familiar states of partial knowledge of space:

- people can know a certain route well enough to follow it in the physical environment, but not be able to describe it;
- people can know a route well enough to follow it in one direction, but not be able to follow it in the other; and
- people can have difficulty solving route-finding problems.

Kuipers' main area of research has focused on exploration by robots moving through a large-scale spatial environment. In his experiments, simulated robots have 16 range sensors and select appropriate reactive controllers while moving around (e.g., following the left wall). When a qualitative change signals the end of a trajectory-following control law, the robot analyzes its immediate neighborhood and selects an appropriate hill-climbing control law. The local maximum of the hill-climbing control law is defined as a distinctive place. By creating an isolated set of distinctive places linked by trajectory-following and hill-climbing control laws, the robot abstracts the continuous world of the robot to the discrete world of a topological map. A geometric map, in the form of a patchwork of localized frames of reference, can be built as a set of annotations on the topological map.

On the basis of this work, Kuipers described a spatial semantic hierarchy (SSH) consisting of multiple representations. He identified four different levels of representation:

1. control: select control laws leading to distinctive states;
2. causal: associate discrete views for distinct states with actions linking them (V-A-V);
3. topological: aggregate views into places, paths, regions, related by connectivity, order, and containment; and
4. metric: annotate places, paths, and regions with frames of reference, distances, directions, shapes, and occupancy models.

The first two are egocentric, while the last two are world-based. Only the causal and topological are symbolic representations; the control and metrical levels are continuous.

SSH levels:

egocentric	1	control: select control laws;	continuous
egocentric	2	causal (V, A, V')	discrete
external real space	3	topological	discrete: places and paths inferred to explain the views

external real space	4	metric	continuous

Kuipers claimed that his SSH model "carves spatial knowledge at the natural joints." It is a big theory of multiple representations and is, therefore, difficult to test. One possible test is that for adequacy. Kuipers argued that single-representation theories are easy to refute since easily observable states of partial knowledge demonstrate that people are actually using multiple representations.

What are the benefits?

- Understanding the nature of multiple representations.
- SSH is robust and degrades gracefully.
- SSH clarifies targets of communication.

Kuipers also offered some speculations:

- There are neural structures that correspond to this hierarchy.
- Insects seem to have the SSH control and metric levels, without intermediate symbolic levels; higher mammals have an increased role for causal and topological levels, and perhaps a decreasing role for metric knowledge.
- The SSH levels (control, causal, topological, metric) will generalize to spatial knowledge and to other types of commonsense knowledge.

Discussion

Following the presentation there was a discussion by participants on humans' ability to process ordinal information. Discussion was also held on how important it is that the distinctions predicted by the theory can be seen in animals. Kuipers responded that there may not be a cognitive capability that is unique to humans and not present in animals. For instance, Kuipers described research by other scientists showing that insects can solve certain spatial reasoning tasks.

5.2 Patrick Hayes' Perspective

Patrick Hayes, author of the *Naive Physics Manifesto* (Hayes 1978) , raised four points that are important regarding common sense:

1. Performance vs. psychological accuracy: getting the machine to do something clever is not the same goal as making an accurate psychological model of human thinking.
2. Interconnectivity of knowledge: spatial, economic, political (e.g., boundaries as an example in the "Naive Geography-paper" (Egenhofer and Mark 1995)); knowledge is not cleanly compartmentalized.

3. Naive projection fallacy, as illustrated by “diagrammatic reasoning”. That people find diagrams useful doesn’t imply that they use ‘mental maps’ to reason with.
4. We should not presuppose the mathematics, e.g., 3-d real space (R3) has many very unintuitive properties and does not model common sense. Maybe we do not have the proper mathematics (yet) and need to develop some new concepts of space, place, etc.

Hayes pointed out the necessity of accurately determining the content of commonsense knowledge even if there is uncertainty whether it is psychologically precise or exactly how it should be represented. He recommended that there should not be too much concern about special representations.

Hayes used as an illustration some recent work on temporality. An attempt to synthesize a single axiomatic model of time foundered when he saw that there were actually two fundamentally different, incompatible, ideas: either a timeinterval is a set of points, or a timepoint is where two intervals meet (Allen’s type of interval). Only the first fits the usual mathematical account of the line. Therefore, it is difficult to get a single coherent picture of time relationships. The situation is likely to be worse for more complex subjects such as space.

With respect to GISs, it is important that a GIS is able to deal with human confusion, which Hayes believes is an important role for Naive Geography. Therefore, we should be interested in those areas at which people are not accomplished, i.e., in which they often get confused. We want to be able to make corrections for these cases. The GIS should complement, rather than imitate, its human user.

What is the content of commonsense knowledge?

> “methodology based on communication is at odds with the idea of a science of common sense” (Hayes)

Discussion

In the discussion following Hayes’ presentation, there were questions about the relationship between Naive Physics and Naive Geography. It was suggested that there may be a spatio-temporal relation. It was also suggested that reasoning about diagrams vs. reasoning with diagrams might explain the mismatch between Naive Geography and Naive Physics. Hayes did not feel that there was actually a mismatch between Naive Geography and Naive Physics, but that they might share a common core of spatio-temporal concepts.

Discussion also centered on whether it was important to have just one theory of common sense and how this big theory might be structured. Might it be possible to have lots of smaller, superficial theories? Hayes agreed that such ‘microtheories’ are realistic and useful, but emphasized the need to find ways to map between them. It was also agreed that small theories are not always compatible, but they do relate to each other. People are able to switch from one to the other without throwing out the first one. Recent work in context logics is probably relevant to this.

It was suggested that perhaps the wrong mathematics is being used to describe this type of reasoning. Perhaps a new mathematics should be considered and thought should be given to what the basis should be for this new mathematics.

5.3 Barry Smith's Perspective

Barry Smith's presentation was on Models, Representations, and Cognitive Worlds. Smith stated that it is a presupposition of talk of what he called "N-disciplines" (naive physics, naive geography, naive biology, folk psychology) that there are stable levels or regions of objects to which our naive or common-sense or untutored beliefs are related. Indeed he claimed that the bulk of our common-sense beliefs are true of a corresponding region of common-sense objects (Smith 1995) . He suggested that it is erroneous to study beliefs, concepts and representations alone, as is standardly done in cognitive science. Rather, we should study also the objects and the object-domains to which our beliefs, concepts and representations relate. Smith suggested further that the idea that there are maps in people's heads, or that concepts or representations go together to form something like maps, databanks, or what one will, is misleading. Rather, the contextual linkages that make our concepts mean what they mean derive not so much from interconnections between concepts inside the head as from interconnections between the cognitive agent and the common-sense world in which he finds himself. If we want to practice good psychology we have to look at the world, or in other words at the ecological niche, in which people live. Psychological investigations should be directed at the ways people relate to the external environment in perception and action (Gibson 1979) , not at internal notional worlds or mental maps.

Smith proposed that, in order to understand this external environment, we should conceive the world by analogy with a big cheese that can be sliced or partitioned in different ways and on different levels of granularity. Our common-sense beliefs effect a mesoscopic slicing; physics effects a microscopic slicing, etc. This leads to a theory, which he referred to as "Compatibilist Mereological Realism" (mereology being the theory of wholes and their parts), which can be applied to explain, for example, how the two identity statements: France is the totality of its 90 departments; and France is the totality of its 311 arrondissements, can be simultaneously true. If "totality" is understood in set-theoretic terms, this simultaneous truth is ruled out (for no 90-membered set is identical with any 311-membered set). If, however, "totality" is understood in mereological terms, then the two statements can be seen as reflecting distinct slicings, or partitionings, of one and the same extended reality.

Smith next considered the opposition between Naive Physics (as part of the N-disciplines) and Sophisticated Physics (as part of the S-disciplines). N-disciplines reflect mesoscopic partitionings, S-disciplines reflect microscopic partitioning. What sort of mappings exist to go from one to the other? In what other ways are N-disciplines distinguished from S-disciplines? N-disciplines deal mostly with qualitative phenomena, S-disciplines with the quantitative and measurable. Physics and biology have their own naive and sophisticated versions. Smith claimed that "Psychology is the naive discipline where neurobiology is the S-discipline." He further argued that ethics and history, for example, do not have S-disciplines. This raises the question, "Is there any S-discipline for geography?"

Note that there are in addition disciplines that are not naive but yet relate to mesoscopic objects that are associated with N-level slicings of the world cheese. Thus there are various specialist extensions of the N-disciplines, including: law, economics, geography, land surveying, planning, engineering, paleontology, and cookery, to name a few. There is trained knowledge of the common-sense world vs. untrained knowledge of the common-sense world.

What are the limits of the common-sense world? Does the belief that the earth is flat belong to common sense? Did it ever belong to common sense? Does common sense evolve over time? Does the belief that babies are brought by storks belong to common sense? Even if everyone believes it? Are N-disciplines genuinely scientific? To answer this latter question, Smith proposed dividing the messy totality of naive or untutored beliefs into two groups (following the anthropologist Robin Horton's distinction between "primary" and "secondary" theory (Horton 1982)). On the one hand are naive beliefs that relate to mesoscopic phenomena in the realm that is immediately accessible to perception and action: beliefs about tables and boats, table-tops and snow, neighborhoods and streets. On the other hand are naive beliefs that relate to gods and angels, heaven and hell, evil spirits and microbes. Smith, following Horton, pointed out that for evolutionary reasons we can assume that beliefs in the former category are almost all of them true (for otherwise all those who held them would be long since dead). N-disciplines, Smith then suggested, should be based exclusively on beliefs in the former category. More precisely they should be seen as the results of systematizing that subset of such beliefs in the former category that satisfy the two further criteria of universality (since a scientific discipline is characteristically not interested in particular truths about Sally's grandmother), and consistency with S-disciplines (since a science, to be worthy of the name, should consist of truths and should be compatible with its sister-sciences).

What is the point or value of N-disciplines as theories of common-sense domains? One answer to this question turns on goal of providing better theories of common-sense reasoning (Hobbs and Moore 1985) . For if common-sense reasoning takes places within (and is all-pervasively intertwined with) the common-sense world, then we cannot understand the former unless we also develop good (even sophisticated) theories of the latter that is to say: sophisticated theories of those objects towards which our naive perceptions and actions are directed.

Discussion

It was mentioned that Geography is a discipline for a common understanding—and that if it did not already exist, people would have to invent it.

The question arose as to what the appropriate methods for Naive Geography might be. Smith stated that we should not use the methods of common-sense reasoning, since such reasoning is unscientific. Rather, we should use genuinely scientific methods to study common-sense reasoning. At the same time we should use these same scientific methods to study the common-sense world of mesoscopic objects that is defined by common-sense reasoning.

But do we really understand the structure of this world? What are its limits? How do we distinguish true and false beliefs about putative commonsensical objects? Smith conceded that much of our everyday lives are spent thinking about what seem to be things outside common-sense reality (think of images, dreams, the objects of astrology); moreover our mental lives are seamless webs: there is no easy way to establish the point where reality ends and false belief begins. Some (metaphysical idealists) have found it tempting to suppose that we are always dealing with images. This hypothesis, however, would leave us with no explanation of how we are able successfully to interact with each other, with predators, with food. The fact of such interaction provides a first explanation of why we must understand that the core of our mental lives is spent dealing with real mesoscopic objects such as persons and rivers and bread.

5.4 Plenary Discussion

The first plenary session of the Specialist Meeting began with a discussion of the inconsistencies in Naive Geography. Consistency is a general problem in theories of naive fields—not just for Naive Geography.

- We have to look for where errors get made.
- We might learn from investigating the inconsistencies that people try to convert into consistent situations.

It was noted that commonsense knowledge about what consistency is varies. Studies of commonsense reasoning, such as those by Kahneman and Tversky, found differences between people's judgments and the predictions of their probability. When people were confronted with their behavior, they often conclude they must have been wrong before; however, people are not usually comfortable with inconsistencies.

Discussion pointed out that under the term inconsistency several different concepts were covered, such as a technical sense (e.g., as in database systems where inconsistency refers to an internal contradiction); irrationality; and changing criteria.

People are good at using abbreviations of theories—when you get to a hard point, stop and build another theory and then join these. It is those "joints" that are the important bits—how you move from one context to another is important. Indeed, one participant suggested that simple theories should not be the goal, but correct theories for the mesoscopic world. You need to extend your simple theories. On the basis of this, another participant wondered if there is evidence that people build more complex theories or do these just happen? It was noted that if you take two individuals and try to combine their views it can be difficult.

This led to the question of whether people should be trying to make machines that perform better than humans, or have them act like humans? One participant reminded the group that there is a paper by Turing written in 1953 on whether you can build a machine that makes mistakes. He asked why would one want to do this? It is probably impossible to build a machine as good as a human. Consistency is probably a characteristic of machines and we should just leave it that. Another discussant pointed out that we want the machine to understand the question being asked and give an answer that the user can understand.

Another topic of discussion in this plenary session was how to construct larger theories from a set of micro-theories given the view of one participant that the S-sciences[1] do not scale up, so Naive-X are efficient methods to deal with complex objects at the meso-level.

It was questioned whether the expert level is the micro-level? Is geography at the micro-level? To this discussant, Naive Geography is not based on Euclidean geometry or correct physics, but is based on high level expert understanding of how the world works.

Another participant explained that micro-theories are used in the CYC project. One theory might state something, such as the land is flat. In another theory you might say something about the earth's curvature. There are inconsistencies between each micro theory. Two kinds of contexts—relevance-based and assumption-based contexts—can add arguments to predications so it is true in this world, but not true in another world. It is possible to have no truth

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[1] Early in the Specialist Meeting, reference was made to that area at the other end of the spectrum from Naive Geography—*Sophisticated* Geography, or *Scientific* Geography, or S-Geography. No firm definition for this type of study was agreed upon during the Meeting.

value for a proposition—a fuzzy value. In response, it was questioned, "What are universals and what are cultural issues?" It was noted that in general, people are very good at coming up with explanations of why they do things. There seems to be a continuum between where your models work and places where your models do not work.

6. The Nature and Definition of Naive Geography

Breakout groups were asked to consider the nature and definition of *commonsense geography* and/or *Naive Geography*:

- What is it?
- What are its characteristics?
- How does it differ from scientific/sophisticated Geography
- Where is it more useful than scientific/sophisticated Geography

Four different views were provided.

6.1 Naive Geography by Example

This breakout group defined Naive Geography by example. Such examples included:

- towns spaced apart
- small towns between big towns
- gas stations on highways
- distributions different in Texas vs. Rhode Island
- bigger towns rather than small
- grid pattern
- commerce associated with exits on Interstate highways

The group felt that humans make use of a rich system of geographic categories and tend to use qualitative reasoning rather than quantitative, and ordinal relations rather than cardinal.

In their consideration of the differences between Naive Geography and Sophisticated Geography, this group felt that a naive approach included representing and applying knowledge of regularities in spatial distributions (e.g., gas station between Austin and San Marcos). However, people often "know" or "believe" things that are not true—e.g., many subjects gave an estimate when asked what they thought the toll was on the bridge between Australia and New Zealand.

Sophisticated Geography, on the other hand, incorporates other dimensions (politics, economics, etc.) to result in more precise deductions (e.g., gas station every 10-12 miles). The group also discussed Naive Geography (just one of them) vs. folk geography (lots of them). And finally, that mapping to/from the qualitative calculus provides evidence for the existence of Naive Geography.

6.2 Key Issues for Naive Geography

The second breakout group reported that they felt that there was no distinction between naive and commonsense geography. They reported that Naive Geography represents what is going on inside people's heads, such that people describe the world and create knowledge structures in their heads. Naive Geography deals with people. Naive Geography is shared by the community.

Concrete examples of Naive Geography:

- Judgments of the desirability of a neighborhood
- Route-planning task
- What are the parameters that matter?
- Direction-giving
- Guide books
- Land-use/environmental planning

With current GIS systems, there is a mismatch between players and GIS data structures. For instance, a system cannot deal with statements like, "That site will have a detrimental impact on the University," or if a user wants a system that can read newspaper or perhaps wants a 911 response system.

The group felt that key issues are:

- Justification
    - Criteria.
    - Tell stories that relate to prototypes we have.
    - Produce variants on prototypes.
    - How do we put naive information into GIS?
    - How do we input natural language ("accident near Long Island").
- Issues
    - Acquisition and use for spatial problem solving, including explanation.
    - GIS provides a tool; AI is model.
    - Monte Carlo simulation of environment; look inside its brain and see what is important.

- Naive Geography assumes permanence of objects (move silverware vs. move car).
- Make GIS easier to use.
- GIS can represent issues that people have about space.
- GIS produces maps not stories.

They identified problems that need to be resolved such as better interfaces and the problems really have nothing to do with Naive Geography. We need to distinguish problems of natural language from those with Naive Geography, and how can we construct Naive Geography from Sophisticated Geography?

Questions left open:

- How does Naive Geography differ from scientific/sophisticated geography?
- Where is Naive Geography more useful than scientific/sophisticated geography?

6.3 Relationship Between Naive Geography and "Sophisticated" Geography

This group defined commonsense or naive [geography] as:

- lack of skill, knowledge
- uninformed yet reliable
- untutored, informal, uninstructed
- "everyday"
- inductively learned? origins inductive, used deductively?
- rule of thumb
- a mixture of some tested ideas, some ideas we just absorb
- children (not pejorative)
- tied up with cultural information; includes experience plus what you have been told, what you have watched
- does Naive Geography hold up cross-culturally?

The group then considered "What is commonsense or naive [geography]? What are its characteristics?"

- We are looking for a declarative essay of a knowledge domain.
- What is important is the content of knowledge rather than the process of obtaining the knowledge.

- How do we communicate commonsense knowledge? Or is it unconscious?
- We should be concerned with the common *use*, rather than the *articulation* of the commonsense knowledge.
- It is about problem-solving.
- What knowledge do we need to invoke to understand others, to solve problems?
- You know context where insight works; some insights move and survive across contexts.
- Naive Geography is comprised of four elements: What we know, how we learn it, how we use it, how we select what is pertinent.

The relationship between Naive Geography and Sophisticated Geography was discussed:

- Sophisticated Geography is beliefs validated by science (the questions asked, how they are asked, how the answers are checked), while Naive Geography comprises those beliefs that are not validated. But is Sophisticated Geography a legitimate benchmark?
- Sophisticated Geography is not necessarily more precise, but necessarily has more explanatory power than Naive Geography.
- Are they different in terms of communication ability? Problem-solving?
- What knowledge do we need to invoke to ask naive vs. sophisticated questions?
- Studying something clearly naive will help us ask different questions; utility of Naive Geography is that questions can be asked that cannot be asked in Sophisticated Geography.

  Will the answers from N-geography questions be the same, or different, from Sophisticated Geography questions? Is one answer more correct?

  > "…[C]ommon sense is merely unaided intuition, and unaided intuition is reasoning performed in the absence of instruments and the tested knowledge of science. Common sense tells us that massive satellites cannot hang suspended 36,000 kilometers above one point on the earth's surface, but they do, in geosynchronous equatorial orbits." (Wilson 1992, p. 86.)

Summary

What are the problems that one can address? Naive Geography is useful for problem solving and detecting differences in questions and answers posed by users. The group concluded that there was no difference between Naive

Geography and Sophisticated Geography in terms of which one is better. It depends on the nature of the problem to be solved.

6.4 Cultural Universals

This group came up with a definition of Naive Geography that was, "An untutored set of beliefs about geographic phenomena." *Geographic* delimits phenomena of a certain spatio-temporal scale, namely "from the village square to the globe." Naive Geography refers to things that are innate, experientially learned, or taught. The group discussed cultural universality and asked whether there are any cultural universals? How much and what kind of training is necessary?

They asked if Naive Geography was better than Sophisticated Geography, and found that the interface is important, as is an understanding of what are human expectations. Naive is sometimes superior and may be important for education and broadening the user base.

Barry Smith contributed the view that all S-disciplines require N-knowledge. For instance, to set up an experiment you have to use N-knowledge.

7. Different Views of Naive Geography

As a start to this session, Barry Smith put forward a summary as he saw it of the four different views of Naive Geography (NG) that had been discussed:

NG 1 describes what goes on in our heads or mind.

May be inconsistent, including typical human error; there are probably individual differences.

NG 2 is the analog to Naive Physics.

A systematic view of NG 1, no gaps, consistent; exclusively primary theory, partially conscious.

NG 3 was seen as the foundations for designing future, intuitive GISs.

Is this the intersection (union) of NG 1 and NG 2?

NG 4 was used as the term to describe the geography of current GISs.

The session began with a question, "How are NG 1 and NG 2 different?" Barry Smith responded that NG 2 is common, universal—what makes successful use of incomplete information possible, etc. It is exclusively primary theory, partially conscious. NG 2 is a systematization of NG 1—there won't be any gaps. NG 2 will be consistent and scalable. NG 3 refers to the use of modules from NG 1 and NG 2; e.g., for GIS user interface design.

When another participant questioned whether Naive Physics included the systematic errors that people tend to make, Patrick Hayes responded that Naive

Physics is not necessarily a single coherent theory, but rather is a family of theories. It was agreed that there should be a family of N-theories and that perhaps NG 2 approach will fail because we lack the theories to build it.

One participant inquired that if NG is not systematic, does it not exist then? Barry Smith responded that our commonsense knowledge of the world is not a theory-like system. We can tell fragmented stories about it. For instance, if you ask people questions about space, they will give coherent answers. Patrick Hayes concurred with this and suggested that we assume there *is* a coherent view.

At this point, most of the group seemed to agree that NG 1 is not coherent and that the problem with NG 2 is that it is most likely to fail and we cannot model with mathematics how the mind puts together these incoherent bits and yet still functions day to day. So that "incomplete" or "inconsistent" are characteristics of these four views of Naive Geography.

It was recognized that parts of geography are based on geometry and the results from geometry are used in geography—so one science is based on another science. And Naive Physics shows the impossibility of aggregating up—just try to explain the physics that actually works, not the theoretical textbook physics. This discussion leads to the stipulation again that alternative topologies or alternative mathematics are needed, and is there naive math or logic, which underlies the way we abstract Naive Physics or Naive Geography and if it exists would we ever arrive at it? Patrick Hayes stated that he has not found a naive mathematics yet and suggested that one could look at the systematic errors that children make as they learn.

Michael Curry raised a concern about issues relating to NG 3. He suggested that people construct a world made out of places and build up a sense of what the world is like—a set of places. How do you deal with the problems that arise when people create certain types of places (e.g., Bosnia, Vietnam)? I do not hear these topics being addressed with this list.

The session closed with a plan to consider what role Naive Geography would play for GIS.

8. The Relationship Between Naive Geography and GIS

Each breakout group was charged with the objective to develop a GIS for the non-expert (i.e., a user with no GIS training).

- What do non-experts use/need?

  May need to pick a particular scenario such as house hunting, vacation planning, or participating in a dispute regarding logging, or vehicle navigation.

- An issue of interface design only?

Is it just an interface issue? Are there other issues?

- How to implement

  What would be things that get recorded or are inferred? Where would Naive Geography extend the knowledge base?

- What would be some typical Naive Geography applications?

  Typical tasks include house hunting; environmental discussion and debate (new shopping mall location, old growth protection, etc.); navigation with vehicle, vacation planning.

This approach led to a compilation of the desiderata for a Naive Geography-based GIS, from four different viewpoints.

8.1 Group One's Desiderata

This group considered question 0: How broad is the scope? Group members felt there is spill-over into other scales and disciplines. They defined Naive Geography for a non-expert, that is any computer tool for geographic problems that has a focus towards problems that never involve a SAP (spatially aware professional).

What do non-experts use or need?

- need to know about relations between things and partially complete information about relations.
- prediction—limited information on coordinates and relations.
- time delays in information input.
- notion of place.
- mundane vs. disaster.

The group also considered whether this was just an issue of interface design, and concluded that input/system/output is a poor breakup of Naive Geography, and that selection occurs at all three levels.

Considering issues of implementation led to a list of important points:

- transforming qualitative information into coordinate space
- leading people through analysis
- sanity checks
- incomplete information
- how to build small theories?
- database integration
- granularity, selection

When considering where would a GIS-II extend the user base, the group discussed if they did not have GIS-I, what would we build? Using commonsense knowledge what would we build? Their answer was, a system that generates or assists an understanding of Naive Geography based on commonsense knowledge and succeeds in breaking a geography problem into tractable question.

When considering how to implement their ideas, the group came up with a categorization of problems:

1. Qualitative information into coordinate space
   - leading people through analysis
   - sanity check
   - incomplete information
2. Database integrations or cleaning of data
3. How to build small theories (making appointments, finding buildings) and how to combine them
4. Getting things in and out

8.2 Group Two's Desiderata

Current GISs are naive. This group believed that there is a need to add commonsense and sophisticated reasoning. The group defined desired functionality and derived a "wish list" of needed technology including, interface, storage, and reasoning issues.

It was decided that one would want the functionality of a decision support system for geographic reasoning. This could aid in policy-level decision making, such as "Should we build a shopping center here? Why or why not?" Or for problem solving at the personal level, for instance, "Should I buy this house? Why or why not?"

The group came up with a technology wish list. First with respect to user interface considerations they believe the following would be desirable:

- flexible query expression
- visual display/interaction
- natural-language understanding
- process display capabilities (e.g., animation)
- explanation

Considering storage issues, they included:

- integration of multiple information bases (knowledge/data)

- multiple (and more powerful) visual/spatial representations
- geometry and semantics
- more uniformity of data

Finally, regarding reasoning capabilities, it was felt there would be a need for:

- sophisticated (scientific) geographic reasoning
- commonsense reasoning
- qualitative and quantitative
- reasoning with incomplete knowledge and uncertainty (e.g., fuzzy borders)

There was some discussion after this presentation as one participant did not believe that is possible to have one model that treats all domains, and another contradicted this view citing the approach taken by CYC to collect the rules needed for different applications and domains.

8.3 Group Three's Desiderata

This breakout group felt that what users need includes usable relevant information (do not overwhelm the user), ready applicability, clarity, a repository for knowledge, analytic power (looking at changes across time, modeling and linkages), privacy, relative to a perspective, and the ability to share a perspective.

Are these issues of interface design? No! However, the group believed that there was a need for a richer ontology, more knowledge, and "naive" knowledge for other domains. Also reasoning about metrics and reasoning by analogy was mentioned.

When considering implementation, the group felt it was premature to consider this yet. Do things in real time—as fast as you need it. There is a need for various levels of detail, and the system must be able to deal with special purposes or unanticipated problems.

Extensions to the user base would include:

- have access to previously uncoded data,
- social theoretic applications, and
- surveillance.

The non-experts' needs include:

- Usable, relevant information. Be able to find a situation and then all the possible information about it, e.g., for navigation, for social services, for a community to track hazardous waste being transported through neighborhoods.

- Ready applicability. Present value-neutral, useful information Is the GIS to actually solve the problem, or to support the user solving the problem? Value-neutral information means making an effort *not* to solve the problem for the user?
- Clarity. Empowering vs. overpowering with information.
- Repository for knowledge. GIS as archive, for utilitarian purposes, for cultural reasons.
- Privacy. The recognition that certain users want lots of data about individuals, but that the individuals do not want so much to be revealed about themselves. What kinds of information should be excluded, e.g., libelous information? *Combining* data from multiple sources into something quite more is an issue.
- Analytic power. Current GIS analytic powers are amenable to use in commonsense scenes.
- GIS to interpolate, to fill in data in a *creative* way.

Interface design considerations include:

- GIS for the non-expert is *not* an issue of interface design only.
- Tradeoff or contradiction–an interface may be easy for the user, but then may hide the way the analysis takes place.
- Are we mirroring naive reasoning or drawing conclusions and presenting them in a naive way?
- More knowledge. Extend N-GIS to natural-language understanding. Main goal of N-GIS is to get knowledge down—the interface is just part of it. Example is house hunting. Want a sense of neighborhoods, not just the ability to extend a four-mile buffer to satisfy criteria for location near a school.
- Analogy. We can take GIS now and put a better interface on it, but we need instead better internal representations for robustness across applications.
- "Naive" knowledge for other domains. Some of the non-experts that use GIS are experts in other domains.
- Reasoning about metrics.
- Various levels of data. GIS seems to have been created for big problems, whereas the naive user often has local-scale questions.
- Unanticipated problems. GIS handles data for special purpose needs now. Unanticipated problems are *the* N-GIS need, where we need capabilities for integration and inference in real time.

Implementation issues:

- Dismissed the implementation issue as premature, except as it led us into the question of expanding the user base.
- Adding geocodes to all kinds of detail raises surveillance issues again (e.g., people with Alzheimer's being implanted with electronic tags).
- How can we extend to human geographers, social-theoretic types?
- Constraining search of the law, documents by *location*.

8.4 Group Four's Desiderata

This breakout group considered some of the problems with current GISs: namely that users must get the system's view and that it takes a long time to learn the tool sets.

Participants discussed what non-expert users need from a system (e.g., for house search, vacation planning, urban planning, vehicle navigation) and came up with a series of topics:

- overview information (flying metaphor as used by the German weather channel)
- dynamic presentation of places
- "electronic binoculars" to look through buildings
- should the system adapt to deficiencies of people or do we need a meeting place?
- compare the spreadsheet metaphor with the desktop metaphor
- keep the power of geography.

They too considered whether Naive Geography was an issue of interface design only and concluded that it was not. For instance, SIMCITY and SIMWORLD have been very popular with users. Their success may be attributed to the fact that they use simple, highly abstract models that users can easily handle and comprehend. There is a need to go from a geometric basis (current systems) to a more conceptual, semantic overlay—an object-centered type of system. Might also want to include sketches and verbal descriptions for interaction. Visualization will be important to overcome overloading of data and different types of zooming should be made available for different tasks

When considering how to implement, the group felt that one should aim for stronger vertical interaction between layers.

Discussion:

In the discussion after the presentation, participants wondered if we are constraining ourselves by emphasizing the geographic part? Perhaps the application of geographic concepts to other kinds of space should be considered.

One of the participants from CYC suggested that a system for commonsense reasoning should have the following elements:

- database integration,
- data cleaning,
- natural-language interpretation,
- natural-language generation,
- knowledge representation,
- map interpretation,
- map generation, and
- semantic text retrieval.

9. Toward Designing and Developing GISs Based on Naive Geography

David Mark presented a schematic to describe some of the roles for commonsense geographic information in GIS (Figure 1).

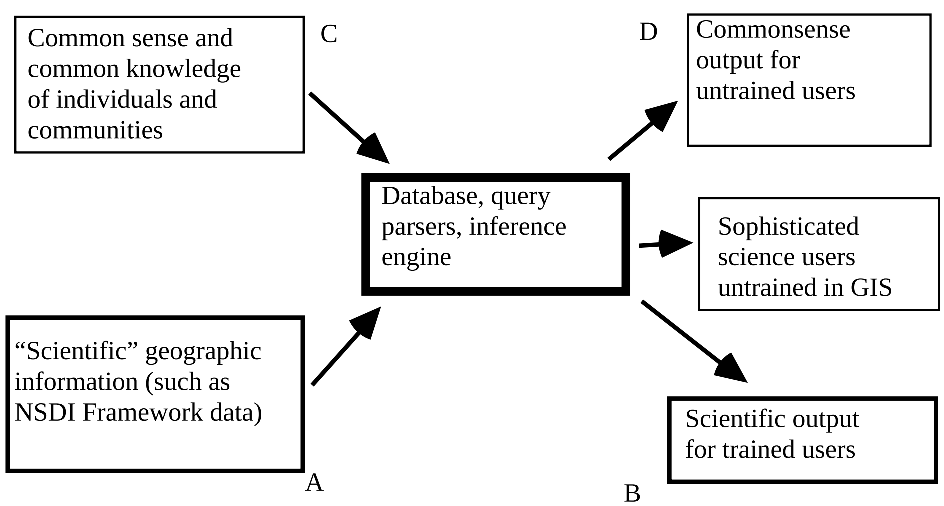

Figure 1: A schematic for roles of Commonsense Knowledge in GIS.

GIS to date has been dominated by a path from A to B. Commonsense knowledge can be part of the input to GIS (C), where qualitative, general, and folk knowledge is put into the database for use by a variety of users, alone or in conjunction with scientific geographic information. Another pathway is from A to D, making scientific GIS data accessible to the general public. A future private community GIS might simply enable the C to D pathway. Five breakout groups were assembled to discuss various aspects of designing and developing a Naive Geography-based GIS.

9.1 System Requirements Based on a Hypothetical Case Study

This group focused on development of a real-world case study involving the spread of a disease. They presented the following scenario:

There are 100 cases of a new disease. Locations and times are known.

Assumptions

- We have a GIS, but without data, although with Internet access.
- Disease, locations of victims, and time of contraction are known.
- GIS users are experts in a discipline, but are not GIS experts.

We are interested in the following questions:

- How was the disease transmitted?
- Where is it likely to go next?
- How to cure it and what can we do about it?

Locations

There are different references of when and where patients got the disease: Coordinate system, postcode, grid reference, etc. There are also textual histories of patients' movements like, "On Saturday I walked down Smith Street, near some park, took a right, along a river, met my friend John and had coffee, got bitten by a rat, and ended up by a church with a great view over the city."

System Architecture

The following steps have to be considered: hypothesis input, data collection, GIS processing, feedback until satisfied or bored.

Hypothesis Input

The system acts as a commentator upon hypotheses. Hypotheses are entered by medics with no special knowledge of GIS.

Data Collection

Data are collected to help making comments on the hypothesis. There are the problems of collecting the appropriate data sets and of data integration of data from heterogeneous sources with differences in the data model, completeness, resolution, and accuracy.

GIS Processing

The system tries to satisfy a set of constraints, for example:

- flows: sewage cannot flow uphill, big pipes do not feed little pipes;
- distance, speed traveled (linked to modes of travel);
- universal constraints: a person cannot be in two different places at the same time;
- diffusion classes and matching spatial patterns;
- carrier constraints (airborne, …); and
- mechanism—spatial pattern is a particular pattern consistent with a particular distribution process.

Possibilities for Output

- "That seems to fit!"
- A refutation, with an explanation.
- "Do not waste your time with that one, because …" (sanity check)
- "You could try …"
- Visualization of the effects of the hypothesis.
- Simulations.

How can one separate Naive Geography from scientific geography? The above example is almost the prototypical case for sophisticated geographic reasoning. What is difference between S- and N-geography in this context?

9.2. An Ontology of Naive Geography

This group worked on beginning the construction of a geographic ontology. Their methodology, inspired by that of Patrick Hayes in his Naive Physics Manifesto (Hayes 1978, Hayes 1985b), was a combination of a priori introspection and mutual criticism and argument. They presented their result, which is reproduced in this report as Appendix 1. It has the form of a hierarchy of kinds of geographic "things," rather like the "feature codes" or "entity types" of a cartographic data standard. Some of the elements in the ontology are defined functionally. Some items in the ontology are properties or attributes, such as "circular" or "linear."

A question that came up during the discussion was, "What do all these terms mean?" The response was that, similar to Naive Physics, axioms would define the meaning of these terms. When it was asked if it was possible to axiomatize these terms, another participant suggested that it would help to look at examples when defining the axioms. Examples could also help to test the axioms in order to arrive at a useful classification.

There was discussion about the method that was used to create the list because the group used a hierarchy. As an alternative, classes with multiple inheritance and interactions could have been used. Tony Cohn replied that the structure of the whole list is not necessarily a tree but parts may be tree-like. It may also be a lattice. A lattice would be more difficult to represent but more likely to be correct. Not all participants wanted to give up the idea of a hierarchy however: "If some things seem to be more important then we should keep the hierarchy."

9.3. Developmental Issues

As an example of scale issues, Dan Montello's typology was presented:

1. minuscule
2. figural
3. vista
4. environmental
5. geographic

Spaces 1 and 5 cannot be known by experience, they are mediated.

One example of a developmental issue is that what may be "environmental" for adults may be "geographic" for children; much research has been done on figural and vista spaces but there has been a lack of research on how children map a large scale environment. Cognitive development of environmental and geographic knowledge is ripe for an approach based on Naive Geography.

Next, an example was presented that demonstrated the utility of a "naive" approach and a specific naive geographic concept:

> Children have been tested with regard to earth shape models.
>
> Children's theories of the earth (Vosniadou and Brewer) => earth is flat (naive?) => earth is round (scientific?)

Children have to adjust with what they have experienced. They do not just get the scientific part, it has to be integrated with naive concepts. There are different mental models of the earth. It was pointed out that there is no universality of content but only universality of process.

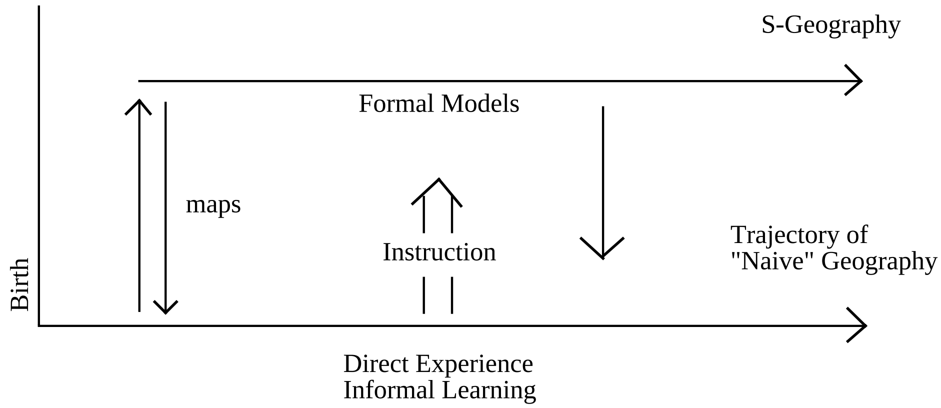

Figure 2: Developmental stages in acquiring naive geographic reasoning.

Three important stages can be identified (Figure 2):

- birth -> maps
- nativist inherited cognitive architecture
- process from birth to Sophisticated Geography

Children acquire a naive geography based on experience. The question is, "What is the relationship between Naive Geography and Sophisticated Geography?" There seem to be trajectories of Naive Geography and Sophisticated Geography, they go in parallel. The third axis in the figure represents time.

Maps are artifacts of S-geographers and children have to come up with this. Children and adults construct maps and we need to understand how they do it. An important question is if formal models are possible without instruction.

It was remarked that we have to distinguish between formal models in geographic textbooks and formal models that are not in geographic textbooks.

The group also focused on the following other issues:

- Spatial vs. geographic knowledge. It is important to answer the question of how much "spatial" relates to the development of "geographic." Another aspect to investigate is the relation of developmental trajectories of the terms "spatial" and "geographic."
- Sources of knowledge/instruction: formal and informal.

Does naive mean uninstructed (or untutored)?

9.4 "What is a Naive Representation?"

The general question here is, "Are naive representations a natural kind (i.e., can they be usefully represented)?"

Some examples were mentioned:

- Subway use: ordinal relations—"functional neighborhood"
- Fire management: overlapping maps vary by informational function (e.g., fire-as-object)
- Blind guidance: GIS + GPS as triggers for talking environments
- "Conference survival:" acquiring San Marcos (pathways [tunnel], landmark, grid)

These are different examples illustrating different forms of representations that might need to be extracted from a GIS (Figure 3). Naive representations must be useful!

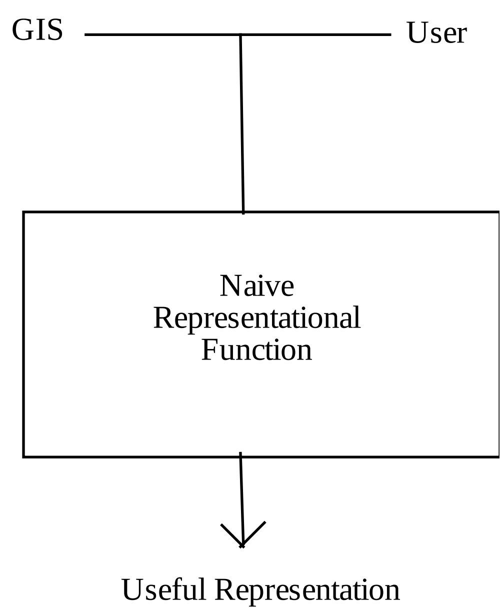

Figure 3: Different forms of naive representations.

The group identified some problems and questions:

- The Naive Representational Function distorts GIS. For example, Boston--------LA (Anaheim)—Anaheim is somewhere around LA.
- Is there a single natural mental map to constrain Naive Representational Function, e.g., anchor theory (Couclelis *et al*. 1987)?
- Is there a generative family of such models?
- Competence/performance, for example, "When do trees become a forest?"

The following conclusions were drawing:

> *If the Naive Representation Function is a natural kind, is it a natural* scientific *kind? The question is, "Can we construct a generative theory of Naive Representation Functions?"*

9.5 Building Naive Theories

Naive theories model observations of the world (predictive theories, not explanatory), such as Euclidean geometry and Newtonian mechanics. There are multiple small theories, e.g., Euclidean geometry is based on five axioms and three objects. It seems a combination of such theories is needed but the question arises of how to maintain consistency when combining the theories. Other problems to consider are uncertainty and approximation.

Linking small, consistent theories would lead to short chains of reasoning. There is a "lift" at predetermined points from one theory to the other.

Small Theories: Parcels

The group considered the following case study:

- parcels
- part (split, merge)
- container (in, out, isIn, …)

These are small theories with respect to parcels but at this level it is not yet possible to differentiate between postal parcels and land parcels. Therefore, we have to add the following:

- 2D large scale objects -> land parcels
- 3D small scale objects -> postal parcels

We need even more aspects to define parcels, e.g., economic objects (buy, sell, own, etc.)

Small Theories: Road

The group considered another case study, a road. A road can be considered as a land parcel, but it can also be considered as a pipe (flow in, out, capacity) or as a barrier (for small animals, such as frogs). There is the possibility to lift 2D to 1D.

Approximations

The problems of uncertainty and approximation were discussed. We need naive rules of observing real world behavior in order to create theories, e.g., heavy objects fall faster than light ones. We have to absorb some of the irregularities into these theories. Engineering and crafts are good examples of how we should build our theories: we build places to absorb error "slack."

As an example, the group gave two theories for the composition (denoted by ;) in direction reasoning:

d ; e = $\{f_1, f_2, \ldots\}$

If you combine directions you get all possible results.

d ; e = f_i (the most likely value)

This theory assumes a single result, e.g., if you put N and E together you get NE. The cost is that associativity is lost. This is an example for absorbing uncertainty, while losing associativity.

The group came up with the following conclusions:

Naive theories:

- are small theories
- combine with lifting at predetermined points to
  - control of length of reasoning chain
  - absorb uncertainty

Problem:

One problem that was recognized by the group is building the foundation classes. The group argued that many of these are linked to image schemata (e.g., container, link, path).

Discussion:

Are the primitives culturally universal? Some image schemata might be universal (e.g., container).

It was noted that the group also addressed the incompleteness question—more specific theories allow to keep the reasoning chain short.

Whereas the group thought foundation classes seem to be linked to image schemata (Lakoff 1987) ; another participant felt, for instance, that it is inexact to say geography is like geometry; there is a lot more than geometry; similarly, many things in reasoning may have nothing to do with image schemata.

10. Researchable Questions

On the basis of the previous discussions and sessions of the Specialist Meeting, participants were charged with coming up with a set of researchable questions. A plenary session was held giving each participant the opportunity to present his/her question(s). The following list of 47 researchable topics was compiled from the plenary session.

10.1 Fundamentals of Naive Geography

The following topics are drawn from Geography, AI, Philosophy, and Mathematics and relate to exploring and understanding the nature of Naive Geography.

- **Geographically-relevant ontologies**

  Develop a suite of geographically relevant ontologies—will be a *lingua franca* to translate between different geographic knowledge bases. To do this, the relevant sort of mathematical tools will be needed—approximate, tolerance geometries, mereology, arrays and embedded arrays.

- **What is "information" in Naive Geography?**

  What is information with respect to layers for Naive Geography?

- **Develop a classification of Naive Geography theories**

  Develop different classes of N-theories in geography—environmental cues, environmental determinism, spatial variation, regionalization, wayfinding, navigation, interaction

- **Assess needs for general vs. specific theories**

  To what extent do we need more general theories vs. more specific theories?

- **Work out a complete, correct Naive Geography, rather than collecting examples**

  Work out the complete correct Naive Geography in order to get at that classification.

- **Characterizing the differences between N- and Sophisticated Geography and the surrounding disciplines**

  Characterize the difference between Naive Geography and Sophisticated Geography from a Horton primary-secondary perspective.

- **Naive Geography theories projected to Sophisticated theories**

  Interested in the role that metaphors play in Naive Geography. Give specific demonstration of cases of Naive Geography theories that are being projected by metaphors and project the experience into the S-domain. For example, the way people reason about weather—this type of reasoning uses a metaphoric projection. This may achieve the short reasoning chains. Take specific case and see what happens.

- **What are the cultural universals in Naive Geography?**

  Look for cultural universals in Naive Geography.

- **Formalize the lexicon for Naive Geography**

  Formalize the lexicon, image schemata, and link to developments to show if these steps are plausible/logical.

- **Formalize image schemata**

  Build a succession of formalized image schemata such that later ones build on earlier ones.

- **Place**

  Place is important in geography and is linked with AI. How is place used in spatial reasoning and what formal theories can be built about place? Can human subjects be used to test our theories of place? Could consider cognitive models of place—children, adults.

- **Scale**

  People think about geographic worlds at different levels of detail. Explore the naive inference methods they apply in and across different scales.

- **Compare table-top space and geographic space**

- **Qualitative reasoning applied to space**

  Techniques employed in (Kuipers 1994) book on qualitative reasoning as applied to space.

- **Advance the tools of standard mathematics or alternative geometries**

  Advances in tools of standards math vs. alternative mathematics. Alternative mathematics and their applications for Naive/Sophisticated geography.

- **Explore alternative geometries**

  Find geometries that could formalize the kind of case study we examined; determine alternate geometric forms that could help to reason qualitatively; alternatives to metric and Cartesian; and alternative topologies.

- **Alternative statistical approaches**

  Come up with alternative statistical approaches that would comply with topological approaches.

10.2 Developmental Influences on Naive Geography

These researchable questions explore the developmental or behavioral aspects of Naive Geography.

- **How is Naive Geography knowledge developed?**
- **Study perspective-switching**

  People have trouble keeping two perspectives at the same time—they switch between them (e.g., going from a map to a route—perspective switching).

  - For instance, learn a layout from one perspective and then make decisions from another perspective and see how long it takes.
  - Learning maps in a certain orientation and using them in the environment
  - Comparisons of graphic overlays on remotely-sensed images vs. more abstract graphic things—moving as well as static.

  Much of this work has been done at the *S-level*. Is anything new to be learned by adopting the naive viewpoint?

- **Exhaustive classification of spatial errors that humans commit (situation-specific)**

  Undertake a classification of spatial errors that humans commit and in which kinds of situations. This relates to states of partial errors.

- **Compare spatial concepts used by children with those used by adults**

  Understanding spatial concepts and how children differ from adults. Very little has been tested experimentally in the past.

- **Learning through exploring**

  Learning a map from sensory perceptions or learning through exploring, e.g., when a person comes to a new town.

- **Find elements of Sophisticated Geography through/in geographic curriculum**
- **How much of Naive Geography is transmitted among people?**

  Transmitting Naive Geography among people—how much is innate?

- **How do people use geographic datasets?**
- **How do people read maps?**
- **Automated map-reading systems**

  Automating the reading of maps—if we know how maps should be read, is it possible to automate them?

- **Study of naive geographic concepts integrated into cyberspace**

  Conduct a study of the naive concepts that are integrated into cyberspace.

- **Use Naive Geography to design better virtual reality systems**

  Applying spatial concepts and virtual reality. What are the constraints brought in from the natural world? What is culturally independent in this case?

- **Use Naive Geography to build virtual environments for training**

  Build virtual environments in which personnel could be trained. These tend to be problem specific. Different systems are being developed for specific tasks. Need more robust systems and general tools.

- **Integration of neural-network representations with Naive Geography reasoning**

10.3 The Impact of Naive Geography on GIS

These questions relate to applications of Naive Geography and the impact of commonsense geographic reasoning on the development of GIS.

- **What kinds of Naive Geography theories will help to design (better) spaces or environments?**

  What kind of theories would help us to design better environments (road networks, airports)?

- **Design information system in which quantitative information holds qualitative together**

  Want the qualitative "glue" that holds together the quantitative layers. Perhaps a Naive Geography can fit together different types of data better.

- **Design GIS that includes qualitative "layers"**

  Consider how human representations of space might improve GIS. Each layer is metrically represented now, but if more layers are to be added to represent qualitative models (route descriptions, etc.), then how are the correspondences between these layers and the quantitative layers created? For example, if a network is combined with a metric map, what kind of output is generated? What are the classes of problems that people want to solve?

- **Methods for "harvesting" geographic databases**

  Look at techniques and tools for extracting patterns in data that exist but are difficult to get at—"harvesting" geographic databases.

- **Design a Web crawler to access geographic information in response to Naive Geography queries.**

  Use a Web crawler (browser) to access geographic information for use by a non-professional user

- **Integration of simulation into GIS (temporal information; process)**
- **Develop "Problem-Solving Support Systems"**

  Could problem support systems be developed that incorporate an intersection between naive systems and sophisticated reasoning systems? For instance, how do you generate a hypothesis from a group of diverse information?

- **How do different Naive Geography theories help resolve, or cause, conflicts?**

  Study how Naive Geography can resolve conflicts.

- **How can we put tools of professionals in the hands of the public?**

  Understand how to put tools of professionals into the hands of the public?

- **Assess incentives to publish geographic information on the Web**

  What are the incentives to publish geographic information on the Web? Are samplers sufficient?

- **When would geographic knowledge mean more power?**

  Where do people not have power? How can a system give them power? E.g., allow a chemical factory to be built in this area? Where is spatial information currently not available but people have needs?

- **Navigation aids based on Naive Geography**

  Application of commonsense geography to the development of navigation aids.

- **How can we translate between producer and user information of geographic datasets**

  How to translate between producer and user information of geographic datasets?

- **What aspects of human spatial/geographic reasoning are better than GIS?**

  There are aspects of spatial thinking that humans perform better than current GISs draw inferences. How can they be formalized and integrated in a system? Incorporate reasoning with incomplete information, creating heuristics that solve problems more quickly than algorithms. What aspects of human spatial thinking are better than current GISs?

- **Cross-cultural comparisons of spatial problem-solving strategies**

  It was commented that individual differences seem to overwhelm any cultural factors.

- **What constraints are there on geographic information?**

  Dealing with incomplete, incoherent information seems to be important.

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Appendix 1:

A Partial Draft of a Geographic Ontology

Conduit

- bi-directional
  - linear
    - route
    - path
    - pass
  - circular
    - roundabout
    - circular tourist route
- unidirectional
  - linear
    - outlet
    - inlet
    - one-way street

Intersection

- confluence
- T-junction

Landmark

- mountain
- clump of trees

Place (complete enclosure)

- territory
- home
- inhabited place
  - town
  - neighborhood
  - village
- region

Topological feature

- surface
  - lake surface
  - top soil
- interior
  - underneath lake surface
- edge
  - frontier
  - barrier
  - dam
  - cliff
  - shoreline
- side/end

Change

- motion
  - seasonal migration
  - searching
- process
  - natural process
    - flooding
    - erosion
    - deposition
    - disease spread
    - periodic change
    - tides
    - seasons
  - animate process
    - producing
    - using resources
    - consuming resources

Change in a property

- temperature change
- land use change
- color change

Egocentric feature

- horizon
- vista
- center

Partition of the world

- body of water
- river
    - lagoon
    - sky
- land

Geometric feature

- geometric feature of land
    - slope
    - cliff
    - flat, plateau, plain
- geometric feature of other entities

Geographic feature

- positive feature
    - shadow
    - forest
    - meadow
    - marsh
- negative feature
    - chasm
    - crater
    - gap
    - fissure

Properties of geographic feature

- metric property
    - absolute
        - width
        - breadth
        - distance
    - relative
        - nearness
- non-metric property
    - density
    - color

Location

- relative
    - here
    - yonder
- absolute
    - place
    - home
    - region

Spatial relation

- containment (in)
    - inside a room
    - inside a canyon
- coincidence (at)
- contact
    - on, support
- direction
    - towards a landmark
    - top/bottom
- between
- center/periphery
- along

Shape

- straight
- curved
- corner
- bent
- nearly closed
    - lagoon shaped

Metereologica

- fire
- wind
- temperature
- precipitation
  - snow
  - rain
  - hail

Institution

- ownership
  - of property
  - of rights
- tribe, group
- jurisdiction
- freedom of movement

Construction

- building
- road
  - road network
- sign
  - road sign
- bridge

Appendix 2:

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