

**SPATIAL ASPECTS OF METAPHORS FOR INFORMATION:
IMPLICATIONS FOR POLYCENTRIC SYSTEM DESIGN**

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Thesis Advisor: Dr. Harlan J. Onsrud

An Abstract of the Thesis Presented
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This dissertation presents three innovations that suggest an alternative approach to structuring information systems: a multidimensional heuristic workspace, a resonance metaphor for information, and a question-centered approach to structuring information relations. Motivated by the need for space to establish a question-centered learning environment, a heuristic workspace has been designed. Both the question-centered approach to information system design and the workspace have been conceived with the resonance metaphor in mind.

This research stemmed from a set of questions aimed at learning how spatial concepts and related factors including geography may play a role in information sharing and public information access. In early stages of this work these concepts and relationships were explored through qualitative analysis of interviews centered on local small group and community users of geospatial data. Evaluation of the interviews led to the conclusion that spatial concepts are pervasive in our language, and they apply equally to phenomena that would be considered physical and geographic as they do to cognitive and social domains. Rather than deriving metaphorically from the physical world to the

human, spatial concepts are native to all dimensions of human life.

This revised view of the metaphors of space was accompanied by a critical evaluation of the prevailing metaphors for information processes, the conduit and pathway metaphors, which led to the emergence of an alternative, resonance metaphor. Whereas the dominant metaphors emphasized information as object and the movement of objects and people through networks and other limitless information spaces, the resonance metaphor suggests the existence of multiple centers in dynamic proximity relationships.

This pointed toward the creation of a space for autonomous problem solving that might be related to other spaces through proximity relationships. It is suggested that a spatial approach involving discrete, discontinuous structures may serve as an alternative to approaches involving movement and transportation.

The federation of multiple autonomous problem-solving spaces, toward goals such as establishing communities of questioners, has become an objective of this work. Future work will aim at accomplishing this federation, most likely by means of the ISO Topic Maps standard or similar semantic networking strategies.

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Part One

**CONCEPTUAL OVERVIEW OF INFORMATION AND SPACE,
FORCES AND STRUCTURES**

Chapter 1

INTRODUCTION

I would like to begin by inviting you to imagine that asking a question could be like tossing a pebble into a pond, then watching the waves and ripples go out until they disappear and merge with the surrounding stillness in the waters, or until they touch the tips of submerged rocks or reflect back from the shore, the waves echoing back in return. Through imagining that the process of posing questions and receiving answers may be more wavelike than it is like the transfer of objects or than the following a paths, a new metaphor for information processes began to take shape, the “resonance” metaphor that is one of the themes that is developed here. This now seems to be a useful complement to the more customary metaphors for information, the conduit and the pathway. Together, these three metaphors provide for a multidimensional approach to information processes generally, suggesting the facets of communication, documentation and learning.

The chapters that follow attempt to consistently present a person-centered approach to information processes that rests in some measure on the resonance metaphor. In the next chapter, several common concepts and metaphors for information will be presented with a view to understanding their implications for thinking about the design of environments for information processes. In particular, the spatial aspects of these constructs are considered in terms of how they may influence the choices we have when participating in information processes. Whereas the conduit and pathway metaphors imply movement of bodies through space and time in the form of information objects or as a searcher traversing a path from uncertainty toward the known, movement in terms of the resonance metaphor is of another order; something moves, but the going out and coming back of waves is of a different character than objects moving on paths. Rather,

the overall image is one of interacting forces that may become harmonics or standing waves when several sources are interacting together.

In addition to suggesting a different order of movement from the conduit and pathway metaphors, the resonance metaphor embodies the concept of center, or having a center or an origin, that serves as an important dimension of the space described by the resonant waves. There is not evidence of center in the conduits for information objects concept, nor is center to be found in the idea that pathways are traveled in accomplishing the changed state from uncertainty to knowledge. Rather, these have spatial origins and endpoints, the input and output portals for the transmission channels, or the place where the questioner is “coming from” on the way to finding where the answer “is at.” These metaphors are often accompanied by spatial constructs that compose complex networks and dendritic trees.

Movement and center are two of the spatial aspects of metaphors for information, one focus of the study presented here. The research questions from which this work originated asked broadly whether there may be spatial aspects that influence information processes generally, especially the processes involved in what is often called “access to information.” Most of the remainder of this introductory chapter will be devoted to an outline of the evolution of these questions within project settings in which they were being asked.

Before beginning that review, mention should be made of a theme that recurs throughout this work, the centrality of questions. This has already been introduced in terms of imagining questions as being like pebbles tossed into a pond. Questions such as “What is ‘information?’” and “What distinguishes question-oriented from answer-driven information systems?” were present at the beginning of this program of study (Schroeder, 1995). The results presented here are composed of a synthesis of the various approaches

taken toward these questions, and suggest a practical direction toward implementing solutions consistent with this synthesis.

The primary tangible product of this effort is the structuring of a digital space that began to take form in terms of a “question space.” Striving to put questions at the center of information processes led to consideration of what sort of space could be constructed that would best let these processes take place. For now, the space that is suggested is the “multidimensional heuristic workspace” detailed in Chapter 8 below. The concept of heuristic, here, is meant to connote problem solving, and asking questions is included in problem solving generally. It is also meant to imply a place for the activity of problem setting as well as that of problem solving; lack of attention to the means by which problems are defined is as responsible for failure to achieve of adequate solutions as is the absence of capacity to adequately follow the implications of the questions at hand.

In this way, the heuristic workspace is a candidate for what a “question space” might be. In analyzing question processes generally (see Chapter 6 below), it became increasingly apparent that questions and answers, uncertainty and knowledge, are all wrapped up intimately with each other. One particular form, the “tensegrity” structure popularized in the work of R. Buckminster Fuller, is a defining figure in the workspace offered here. Because the emergence of a question implies a sort of tension, and the attainment of answers implies a moment of stability or resolution, the tensegrity form which balances containing forces of continuous tension and discontinuous regions of compression seems a good physical and geometric match for representing the interpenetration of questions and answers in a mutually dependent structure.

These are the main themes and results that will be presented here, that questions rather than knowledge can be conceived as the center of many information processes, and that the existing repertoire of metaphors for information might be expanded with benefit for the creation of such question-centered spaces. A particular structure is offered that is

thought to be robust enough to accommodate the great variety of forms and relationships that might be forthcoming in many questioning or problem solving situations.

An additional motivation that accompanies this work is the desire to conceive of information systems that are pluralistic, that allow people who have a stake in their own knowledge and local understandings of the world to autonomously preserve that knowledge against prevailing tendencies toward standardization and universalization. The particular solution given here, if implemented along the lines that are suggested, represents a “polycentric” approach to preserving autonomy and diversity, while affording visibility to others who may share in some measure the questions and answers organized in any particular space. By a process of bringing questions into mutual proximity through defining communities of questioners, the existing hierarchies that separate those who want to know from those who already do might be mitigated.

Background and Context for This Work

The rest of this chapter will be devoted to a review of some earlier approaches that were taken and of the groups and projects which provided context for the emergence of the results reported here. The most immediate and relevant project is an interdisciplinary experiment named New Directions Downeast (NDDE), which will receive the most detailed description of the projects reviewed here.

At its earliest stages, this research began with the intent of mapping information networks, or the “information infrastructure,” especially with a view to the expanded capacities for local institutions such as libraries and schools to locate and retrieve information resources from an increasing number of sources due to the expansion of the Internet and related information and communications technologies. Initial focus was on the expansion of Internet points of presence through telephone dialup and direct connections to shared public networks in the setting of rural Maine, see (Schroeder,

1996a). The important distinction between an “communications infrastructure” and an “information infrastructure,” which are often confused in everyday speech, became clear through this work. An example of ongoing work concerned with innovations in charting the global communications networks is Dodge’s *Atlas of Cyberspace* (2001).

As the focus turned toward charting the information infrastructure, particularly mapping of “public information access,” the need for better understanding of core terms such as “information” became apparent. Attempts were made to visualize information access by means of a geographic metaphor expressed through contours, valleys and flow networks, as might be implemented in approaches such as friction surface mapping supported in geographic information systems (GIS). This approach was in the spirit of Mitchell’s suggestion, in *City of Bits*, that the character of Nolli’s early 18th century map of Rome, which Mitchell claims depicts that city’s “customs, norms, and laws governing rights to privacy, access to public and semipublic places,” could find expression in a digital environment: “Perhaps some electronic cartographer of the future will produce an appropriately nuanced Nolli map of the Net”(Mitchell, 1995, p. 131).

It became clear that “access” itself is a problematic term for what is meant by participation in an environment of common information resources. Access turned out not to be dependent on quantifiable conditions such as distance and barriers, as often conceived, and relied much more on situational needs, motivations, and social standing and relationships among participants. If any “access” structure were to be mapped, it would need to be based on a broadly participatory mapping process. Participatory approaches to information access mapping were suggested in (Schroeder, 1997b). Work on the use of geographic metaphors for visualizing nongeographic relationships is a continuing research theme in the geographic information sciences, see Skupin and Fabrikant (2003). The approaches they report are aimed at creating innovative and

effective visualizations of existing data sets, a goal that is somewhat different than the goal that is adopted here.

The participatory theme was also one concern of a community of researchers who were addressing the social effects of the proliferation of new information and communications technologies such as GIS, particularly those involved in National Center for Geographic Information and Analysis (NCGIA) Initiative 19: GIS and Society (Harris & Weiner, 1996). This effort included the organization of a workshop on the theme of “public participation GIS” (PPGIS), see (Schroeder, 1996b) and the crafting of a theoretical basis for PPGIS in terms of the “criteria for the design of a GIS/2” reported by Sheppard, Couclelis, Graham, Harrington, and Onsrud (1999, p. 811). The main tangible outcome presented here, the multidimensional heuristic workspace, embodies several of these criteria, including an increased emphasis on the role of participants in creation and evaluation of data, the equitable representation of diverse views while preserving contradictions against premature resolution, reflecting the objectives held by each participant, allowing integrated media and informal sources, and allowing for the use of alternative coordinate systems.

In these ways, attempts to visualize information relationships changed during the course of this work, from the geographic, to networks, to the federation of autonomous workspaces. Consistent with the focus on public participation, an empirical research project was undertaken with support from the Federal Geographic Data Committee. This was an effort of learn from qualitative sources (open-ended interviews and small group discussions) about how information resources were being managed and shared among GIS users in rural and coastal Maine communities. The goal of the interviews was to learn if there might be a particular “spatial” component influencing information sharing behavior across communities and projects. At the wrap-up meeting for this project (May, 1999) an attempt was made to correlate geographic locations of community-based

participants with their primary sharing partners, through an exercise in which participants drew social network sketches in correspondence with sketches of geographic regions of interest. Some of the motivation for this came from the work of Paulston and Liebman in the “social cartography” concept they have advanced in (Paulston & Liebman, 1993) and in the essays collected in (Paulston, 1996). At the same meeting there was discussion of alternative metaphors (then termed models) for information, including billiard ball, digestive and reflection metaphors. This may have marked the effective end of the empirical stage of this research, and beginning of a rethinking of the dimensions of the problem that is being addressed.

The effort to systematically evaluate the data texts gathered from these interviews and from participation in many other community-based meetings focused on information sharing (particularly meetings of the Gulf of Maine Environmental Information Exchange, see (Schroeder et al., 2001)) stalled due to the absence of any theoretical frame within which this spatiality of information sharing could be evaluated. The development of a list of core concepts related to space and to sharing with which to code the expressions found in the interviews (see Appendix A: Spatial Terms from Codebook 3) led to a growing sense that spatial concepts and thinking pervade all human dimensions, and are as intrinsic to the social/cognitive world as found in sharing processes as they are to the geographic and physical dimensions. The texts were used to clarify exactly how to identify “questions” that came up during the interviews, as raised by any of the participants. This approach reflected the overall sense that attention to questions might provide an avenue toward analysis of sharing relations, and the recognition of spatiality across questions and involving communities of questioners became a main focus of investigation. Part of the process of identifying questions, and learning about the difficulties in specifying questions, was undertaken in the form of an intercoder agreement exercise. For details on the place of intercoder agreement in

qualitative text analysis, see Carey, Morgan and Oxtoby (1996) and Harris, Pryor and Adams (Harris, Pryor, & Adams, 1997).

The attempt to analyze the interviews and public meetings sharpened awareness that what are often considered to be “barriers to information access” are mainly social rather than technical or physical. The need to reframe access in terms of inclusion and exclusion rather than in terms of access is an important perspective to have emerged in this work (Schroeder, 1999). The workspace outlined below is meant to allow the values of autonomy, transparency and inclusion to be part of the design of the information system.

An important outcome of the attempt to perform text analysis was the exploration of various means to manage codebook terms. These codes were managed at first within the text analysis software being used, AnSWR: Analysis Software for Word-Based Records (U.S. Centers for Disease Control, 2003), which allowed the terms to be structured in lists and in simple hierarchical network trees. Visualizing links among the code terms was not possible. Cross references could be embedded in the text descriptions of each code, but there was no way to physically see those relationships. In a first step toward this visualization, all terms were entered in cross-referenced form in the semantic visualization software SemNet (now discontinued; superseded by Semantics, see (Semantic Research Inc., 2002) improving on the scheme offered in AnSWR but limited to views that allowed only one core concept to be seen at a time, with its immediate first-order linked terms. No overview of the entire network was possible. In addition, SemNet required the establishment of explicit defined links – a requirement that worked against a dynamic re-arrangement of concepts. The Axon Idea Processor was then found to resolve these problems, allowing total network views and management of relations in the form of clusters as well as explicit links (Axon Research, 2003). SemNet and Axon were located through Kathleen Fisher’s *Concept Mapping / Semantic Networking / Knowledge*

Representation online resource page (Fisher, 2001). Though Axon provides a multi-level environment within which to organize concept relations, how to put Axon's levels to effective use was not apparent until its undifferentiated space was used as environment for the creation of a multidimensional structure as described in detail below, and in Chapter 8. One of the significant outcomes of the present work, pointing toward future directions, is the creation of a flexible three-dimensional space within which to manage codebook terms for qualitative text analysis.

Given this background, the catalyst for the results given here was found within the questions and discussions of New Directions Downeast (NDDE), part of a national effort supported by the National Science Foundation and other sponsors that seeks to bring earth scientists and humanities scholars together in interdisciplinary team projects. The particular project of NDDE is titled *Visualizaing a Digital Library for the Gulf of Maine Region*. Details about New Directions Downeast, including links to meeting summaries and information about the national project, are available online (New Directions Downeast, 2001-2003); a summary report after the project's first year has been written, that also sketches some of the outcomes presented in this paper as they relate to the NDDE (Schroeder, 2003). Particularly important were the emergence of the "resonance metaphor" from these discussions, partly based on a graphic that had been created within the project for discussion purposes, *This Corner of the World* (Figure 1).

The following paragraphs detail some of the discussions which led to the production of this graphic, and then relate it to the emergence of the "resonance metaphor for information" within the NDDE process as a whole. One of the main motivations for the digital library discussion was toward expanding the usefulness of an existing resource

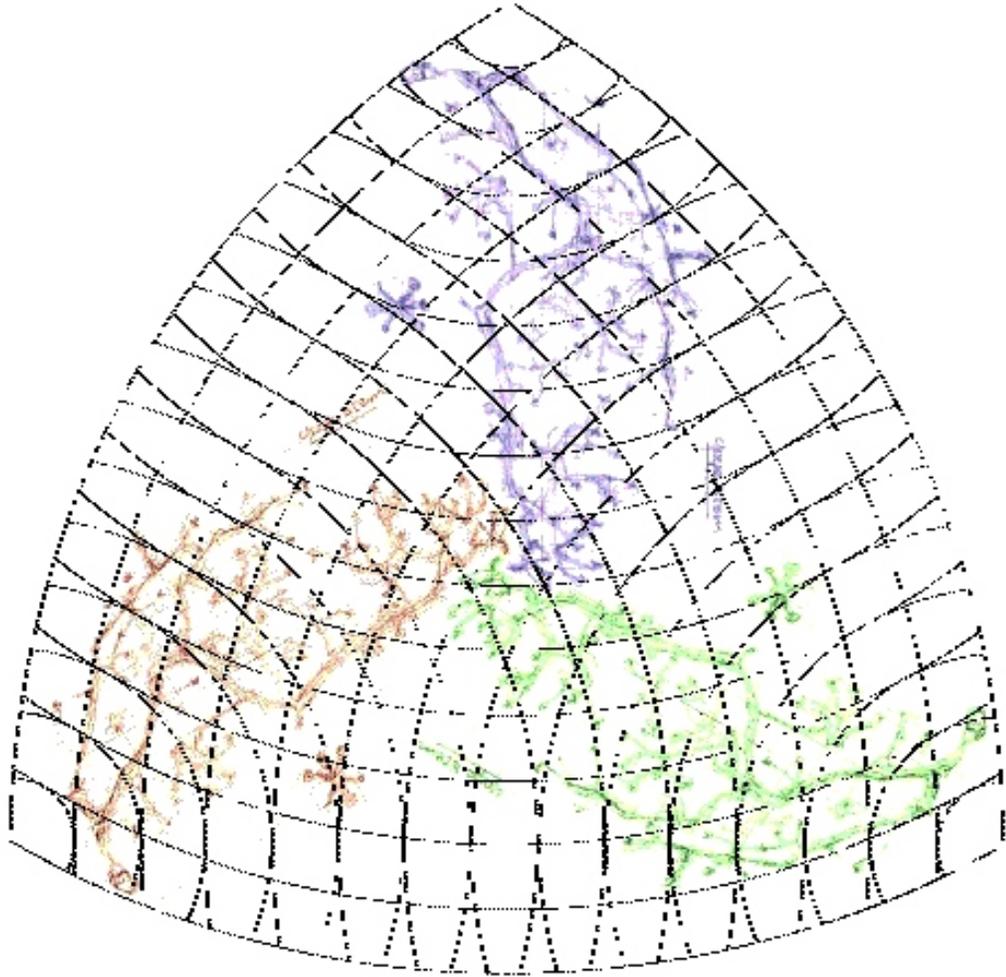


Figure 1. *This Corner of the World.*

under development, the United States Geological Survey's Marine Realms Information Bank, begun as a facility to provide access to USGS coastal and marine programs research results (USGS, Coastal and Marine Geology Program 2003). Early in the process, one aspect of visualizing a digital library received particular attention, the goal of creating an interactive learning environment of which the resources of a digital library would be a part.

Early discussions included questions about who the intended users of this expanded information resource might be, and what real needs of local communities, resource managers and other scientific researchers might be served. To the extent that very different communities of interest would be invited to participate and make use of this resource, how could the ranges of interest be accommodated by means of an improved MRIB? Was there a way to define the dimensions of a "common language" across the communities of interest in order to make the resource more welcoming and more useful? The development of this common language would seem to depend on the availability of a setting for the negotiation of shared meanings, a setting that also does not yet exist except indirectly in the legal and political process. Another pattern that emerged was the assumption, in the construction of a knowledge-based information resource, that its function would be to provide knowledge on behalf of those who have created it, for the benefit of others for whom this knowledge is absent.

Questions that emerged about both of these assumptions are part of the background for the particular solution that is offered in the present work. First of all, it became apparent that a "common language" (sometimes referred to as a shared "ontology") could not be defined prior to the establishment of an interactive environment within which this language could be spoken. The first task seemed to be one of creating an environment for the emergence of shared meanings, rather than by specifying a shared ontology by means of user studies, analysis of information categories, and so forth.

In addition, the pattern of thought that set one community of participants aside as being those with expertise, somehow distinguished from others presumed to be lay learners, would perpetuate a hierarchical structure that would stand in the way of the open discourse that would need to precede the emergence of a common language. It was this insight that led toward redefining questions as being interwoven with answers. All knowledge, it became clear, rested in some measure on prior questions, and all questions are based on significant though at times limited pools of knowledge. Any solution toward creating an interactive learning environment would have to level the field in terms of knowledge held by all participants. An initial attempt to explain the dimensions of a proposed question-centered approach to information system design was presented as a contribution to the Foundations of Information Science 2002 online conference (Schroeder, 2002a).

Discussions among NDDE participants from the Orono group in the early summer of 2002 began to point toward a synthesis in keeping with the concerns outlined above: “How do you have discussion between people with very different frames of reference and modes of thought? . . . Looking for a metaphor that can be translated into a form that is helpful in bringing people and their questions into closer proximity. . . . How can questions maintain their self-identity while moving in an environment of other peoples’ questions and answers? . . . Perhaps most important, defining communities of discourse and who is part of them. . . . MRIB’s organization speaks to differentiation, to ‘hermetic separation.’ Does not speak to commonalities, integration and synthesis. Are there processes that cut across these disciplines: studies of cyclic process; perhaps needed, a way to present this, highlighting linkages in a nonhierarchical form. . . . Always aware of how limited are the horizons and knowledge of [one’s] own discipline. . . . Goal: actualizing people’s contributions.”

Eventually, a direction suggested by the following question emerged: What if we thought of asking a question as being analogous to throwing a pebble into a pond? This became the “generative metaphor” (Schön, 1979) from which many of the results described in detail below followed. A generic graph that might be of help in situating questions was created, taking on a shape reminiscent of intersecting great circles on a sphere, with wavelike lines traversing the enclosed space, all overlain upon three non-intersecting branching tree networks. The basic overlay was obtained from the public domain design resource, *Design on File* the form of a graph titled Scatter Graph 1 (Diagram Group, 1984, p. 4.014), whereas the dendritic branches were drawn from a grape stem that had been used earlier as a physical model that gave substance to the concept of a hydrographic network. The result became *This Corner of the World* (Figure 1), which will be referred to throughout the paper below as the two-dimensional base for what became the multidimensional workspace.

One participant recognized the need for imagery not only to represent things that are present, but the importance of all the factors that may have been left out of any particular description or representation, often of as great importance for ongoing work than what everyone has agreed to include. He noted (see NDDE Orono minutes of August 30, 2002) that conversations of people who have very different interests results “in a few nodes of intersection, but most of it is [pause] nothingness. [pause] To me the vast nothingness [signifies] the missed opportunities of communication. So, how do we bring them into sync with one another, so that they will resonate? I think that’s really what our problem is, what our brief is in this project.”

This statement, in tune with the relationships expressed in the graphic, seems to have been the first appearance of the “resonance” concept within NDDE discussions. It would be brought into much sharper focus during the meeting of participants from all

three project nodes a few weeks later; see detailed meeting transcript at (New Directions Downeast, 2002).

Explanation of the graphic began with the generative metaphor of questions' being like stones thrown into a pond, the result represented in the figure by wave propagation across its surface, a surface already suggesting other dimensions. The lack of defined elements and regions would leave room for ambiguity, another objective that had been raised. The three corners could represent three dimensions, with waves emanating from each combining forces in three directions. In this way, the harmonics, resonances, standing waves and dead spots between the waves could be considered. The figure is also reminiscent of a Venn diagram; intimates relationships across phenomena whose locations and paths might not be known; and suggests the presence of disturbances and reflecting surfaces. In addition, the intersecting waves suggested the possibility of defining a coordinate system in terms of what appeared to be great circles, an approach to global map projection used by R Buckminster Fuller (1975bp. 710 ff.) that was just becoming known to members of the NDDE discussion.

At this point it should be noted that *This Corner of the World* also portrays three nonintersecting root and branch stems that were originally conceived as a visualization of various pathways that might be taken in information searching, or that might be useful in categorizing nested concepts that often are appropriate when identifying information conceived as objects arranged in hierarchical levels. Of particular importance is the fact that these never intersect, that no direct path linking the branch structures is possible within the terms of the graphic. These nonintersecting branches were taken to represent the necessary discontinuity of various aspects of cognitive process – the same discontinuity that Dervin makes a core condition of her “sense-making” process of information; see (1992, p. 62). The branch structures also modeled, or represented, ideas about information exploration that had been discussed in NDDE sessions, including such

notions as “tunneling” and the idea that relevant information resources might be viewed from distances, or seen in illuminating “pools of light” (a pattern in Alexander and colleagues’ *Pattern Language* (Alexander, Ishikawa, & Silverstein, 1977, p. 1160 ff.)) without affording direct physical access from one position to the others. The importance of dendritic patterns is noted by Prescott and Richards, who comment about their sculpture *Arbor Vitae* in these terms: “Making sense of the world is a process of making connections, using analogy, metaphor and the noticing of patterns. Many of the patterns we recognize and our processes of organizing them are dendritic in form” (1999, from explanatory plaque). The incorporation of such forms into the workspace is intended in future work.

After the presentation of the graphic, Fausto Marincioni of the USGS coastal and marine center in Woods Hole, MA remarked that it reminded him of a “reverberation” model of information suggested in a work by Sarah Michaels as part of an explanation of how information related to natural disasters, particularly earthquakes, was disseminated (Michaels, 1992). There was no graphic illustration of this concept in Michaels’ article, but Fausto thought that the *This Corner* graphic might be a good candidate to illustrate it. In the article, Michaels suggested that a process of “reverberation” might characterize passage of information within “issue networks,” the informal cross-cutting connections between researchers and managers that were critical in preparing for and during natural disaster emergencies. Viewing the earthquake policy community as a whole, Michaels suggested that “information does not flow through such communities, it reverberates among various nodes of the networks and often gets lost along the way” (p. 161).

It seems particularly appropriate that the present set of questions being asked by geologists, now attempting to be resolved through a new metaphor and related experimental structures, has been advanced with the assistance of a “reverberation” concept of information as suggested by a student of earthquake information –

earthquakes providing information about their own existence known through resonances propagated across and through the entire globe.

The heuristic workspace presented here is a variant on a structure or facility that has been termed “participant observatory.” This idea was first presented at a conference in 1997 (Schroeder, 1997a) and an update on its progress was recently (2002b). That concept was included in the experimental organization Gulf of Maine Environmental Information Exchange, and was mentioned in the published summary of that effort (Schroeder et al., 2001). There is also a similarity between the overall idea presented here and the “cognitive laboratory” that was suggested as a setting for a program of “heuristic research” by Herbert Brun (1974).

Conceiving a Unified Coordinate System

The section above details the attempt to visualize a space that could accommodate an “interactive learning environment” to complement the functions of a regional digital library. A shift away from knowledge-based information systems toward question-centered learning environments is attempted. This reflects the figure-ground shift between data-centered and human-centered approaches to information, a prominent theme in Chapters 2 and 4 below.

Beyond the motivating situation of the New Directions Downeast discussions, one additional theme that recurs throughout this work needs to be introduced here. This is the intuition that we humans inhabit a single world that has physical and geographic as well as social and cognitive dimensions, and that these are interrelated much more closely than our everyday distinctions often suggest. The intimation of this single field, that suggests the possibility of an approach to crafting a coordination of coordinates, first came from exploring the spatial terms that might be used in descriptions of information sharing processes (see list of terms in Appendix A).

As Mark Johnson puts it, “as animals we have bodies connected to the natural world, such that our consciousness and rationality are tied to our bodily orientations and interactions in and with our environment” (Johnson, 1987, p. xxxviii). Difficulties encountered in maintaining distinctions across these dimensions has led to a growing sense that we live in a single, unified space; that space and spatial terms pervade all aspects of our existence; and that any approach to understanding spatiality in human terms should attempt to look at these as the several dimensions of a single coordinate system. This sense is expressed by Hutchins in stating his own goals, aimed at relaxing the boundaries that “have been erected, primarily for analytic convenience, in social space, in physical space, and in time” (Hutchins, 1995, p. xiii).

There is a tradition of similar thought within the discipline of geography. Entrikin addressed the problem of how to reconcile two major trends in geography, which he calls the empirical and the phenomenological. He notes that in contrasting the existential space of the phenomenologists and the metric distances of the empirical geographers, “the question arises as to whether these two distinct spatial perspectives can be reconciled within one philosophical framework or represent two divergent paths of geographic thought” (Entrikin, 1977, 209). Each of these approaches assumes that the spatial concepts used by the other are extensions of its own, as for instance we may uncritically assume that discussion of space in social domains is essentially a metaphoric extension from physical geographic space.

This question persists in discussions of geographic theory until today. Doreen Massey proposes that a thorough reconsideration by geographers of the concepts of space and time may help to build a bridge between the natural and social sciences, including their expressions in geography (Massey, 1999). An intimation of this bridge may be seen in the use of regular polyhedral forms in the heuristic workspace presented below, compared with a similar base now being explored by geographers who are exploring

alternatives to the dominant Cartesian latitudes and longitudes in use today; see for example the approaches of Sahr, White and Kimerling (2003) and Dutton (1991; 1999). The possible coordination of the present approach with these is suggested in the section on future work in Chapter 10.

This chapter has introduced some of the motivations that have prompted the present work, and has detailed some of the contexts from which these motivations came and in which they have meaning. The chapters that follow will present the theoretical considerations that were pursued, given the questions that arose in these project settings. The major outcome, a structured multidimensional workspace based on a resonance metaphor and question-centered orientation, is described below in Chapter 8, with a sample application given in Chapter 9. A summary of conclusions and indication of future work are presented in the final chapter.

Chapter 2

CONCEPTS AND METAPHORS FOR INFORMATION

This chapter will review several familiar concepts and metaphors for information, suggesting some of the practical consequences that these may have for the choices that we make about negotiating within and designing for our information environment.

Lakoff and Johnson, whose work forms the basis for many of the ideas that are presented in this chapter, point out that our concepts “govern our everyday functioning, down to the most mundane details. Our concepts structure what we perceive, how we get around in the world, and how we relate to other people” (Lakoff & Johnson, 1980, p. 3). We are often unaware of how our concepts are structured, often in the form of basic metaphors, and how these structures determine our approach to everyday situations and activities. Because our most familiar concepts are embedded in our customary patterns of speech, the opportunity to have access to alternative constructs may be to some extent unavailable, or even inconceivable, to us.

A simple example is given by Lakoff and Johnson to illustrate this point. After elaborating what they call the “argument as war” metaphor, which is a well-established structure of thought in our culture, they suggest that we might imagine a hypothetical culture where “arguments are not viewed in terms of war, where no one wins or loses, where there is no sense of attacking or defending, gaining or losing ground. Imagine a culture where an argument is viewed as a dance, the participants are seen as performers, and the goal is to perform in a balanced and aesthetically pleasing way” (p. 5).

In this spirit of imagining alternatives, after the more familiar concepts and metaphors for information are presented, an approach is made toward alternative constructs, in an attempt to extend our working repertoire of metaphors. These alternatives are not intended to be replacements for the existing, established constructs,

which do fit many of the processes involved in what we think of as information. Rather, understanding the implications or consequences of our present constructs, their “entailments” as Lakoff and Johnson term such consequences, may indicate how alternatives might expand choices that are perhaps less available to us now.

Three concepts of information (here termed the transmission, natural resource, and cognitive / constructivist approaches to information) with three metaphors (conduit, pathway, and resonance) are presented here. The overall approach of this thesis emphasizes the importance of the third concept of information, the cognitive / constructivist approach, which is often neglected or not fully exploited even when recognized as being important for the design of information systems. The resonance metaphor is offered as an alternative or supplement to the more familiar conduit and pathway metaphors. The alternative approaches to design that are suggested in later chapters, including the concept of question-centered learning environments in contrast to knowledge-based information systems, and the potential of a new “heuristic workspace” that aims to operationalize some of the new possibilities made available through examining and extending our concepts and metaphors of information.

Three Concepts of Information

Before exploring the metaphors that often frame our everyday approach to what we think of as information, information processes and our information environment, three distinct concepts are presented that are frequently encountered in the information sciences literature and related formal thinking about information. These share some characteristics with the metaphors that are described in later sections, though the metaphors are generally less explicit, and are more embedded in other contexts of everyday thoughts and actions that extend beyond issues of information.

The sections that follow outline three approaches that address the question, “What is information?”

Information 1: The Signal / Channel, or Transmission Concept

Of the commonly recognized concepts of information, the one that is most technically oriented and closest to the information sciences is based in Claude Shannon’s “mathematical theory of communication” (Shannon & Weaver, 1949/1964). Reference to this approach to information occurs widely in information science literature. The brief outline presented here is based largely on explanations of Shannon’s work and its ongoing importance as provided by Jeremy Campbell (1982).

Campbell summarizes Shannon’s primary concerns as being “order and disorder, error and the control of error, possibilities and the actualizing of possibilities, uncertainty and the limits to uncertainty” (p. 17-18). Shannon’s problems were set in the engineering of communication systems. The occurrence of terms such as signals, messages, channels, noise, feedback, communication and control, variety, order and entropy are common in the Shannon tradition, and in the cybernetics of Norbert Wiener (1948/1961). Most of these terms, as well as information itself, have technical definitions within communications theory that for the most part are not understood and that even go against everyday understandings of their meanings.

Shannon observed that energy and information both could be seen as exhibiting the process of entropy. His theory was based on the physical laws of thermodynamics describing the behavior of energy, deriving from the work of Clausius and elaborated by Boltzmann. These are expressed in what Campbell calls the “famous couplet” of Clausius, “The energy of the universe is a constant, the entropy of the universe tends to a maximum” (Campbell, 1982, p. 37). “At the heart of the second law is the insight that order has value. It enables new forms to be created out of old forms. It makes life

possible, and civilized societies. And it is intimately connected with meaning” (p. 41). Shannon extended the physical operation of the laws of thermodynamics to communication processes. For him, "nature" is no longer just matter and energy, but “Nature must be interpreted as matter, energy, and information” (p. 16).

Campbell suggests the example of the organization of books in a library as one means toward understanding the relationship between the concepts of information and entropy in Shannon’s theory. Information and entropy act as reciprocals for each other. If there is only one way that the books can be arranged, and that order is maintained, then there is a condition of low entropy, disorder is minimized. If the books are randomly scattered (recalling one image of the organization of the World Wide Web as a library that contains all the books in the world but they are scattered on the floor) there is a condition of high entropy, or disorder. The natural tendency toward disorder is expressed in the second law, above, “the entropy of the universe tends to a maximum.” Thus, information tends toward a minimum. “In the library, high entropy means lack of information. It means uncertainty” (p. 46-47).

The relationship between information and order is a concept that occurs throughout discussions about information. The tendency toward disorder helps to define the actual tasks facing information specialists; since entropy is “an irreversible process. It does not decrease unless some extra source of energy intervenes to push it back . . .” (p. 49) then information professionals may be considered to be negentropists, working against the push of natural forces to maintain a world that is informationally useful. As will be seen in discussion of the third concept of information below, this process of making order is not just the task of information specialists, but is intrinsic to all human activity related to expression and understanding.

Among the problems that accompany this approach to information, as noted by Campbell, is that “disorder is not a wholly objective property” (p. 32) For purposes of

this theory, concerned as it is with the coding and decoding of signals passed through channels of communication, there is a relationship between probability and information, “because the first cannot be defined without the help of the second. In Shannon’s theory, entropy is a probability distribution, assigning various probabilities to a set of possible messages. But entropy is also a measure of what the person receiving a message does *not* know about it before it arrives. Entropy is an index of his uncertainty as to what to expect. If the entropy is a maximum, that is to say, if all the possible messages are equally probably, then his ignorance is also a maximum.”

In cartography, and the realm of geospatial information systems generally, maps and other systems of geographic representation have sometimes been considered as being channels for the transmission of information, and as control and feedback devices in the Shannon tradition. Robinson and Petchenik devote a chapter to the “map as communication system,” providing detailed descriptions from the cartographic literature in terms of the Shannon model (1976, pp. 23-42). In a more recent work, MacEachren (1995, p. 459) critically evaluated the “communication paradigm” for maps as having “floundered due to a fundamental assumption that matched only a small proportion of mapping situations: maps as primarily a ‘vehicle’ for transfer of information.” He presents an alternative concept, that he terms a representational perspective, which is more in line with the cognitive / constructivist concept of information as presented below. Robinson and Petchenik (1976, p. 88 ff.) report the implications of Jean Piaget’s work for understanding maps of the work of Piaget and his colleagues who are identified with a constructivist approach to cognition. “Our review in Chapter 2 of the map as medium of communication noted that recent methodologic writings in cartography have emphasized that the percipient is an integral functioning component” (p. 108).

For purposes of the discussion that follows, generally, the Shannon theory can be conceived as being more concerned with preserving the integrity of signals passed

through channels, against the forces of disorder collectively known as noise. As such, there is a close affinity between this concept and the “conduit metaphor” that is explored in detail below. The critical analysis that Reddy provides regarding the conduit metaphor rests upon his observation of the insufficiency of approaches based in the Shannon tradition, and will be further discussed there.

Campbell, summarizing Shannon’s approach, says that the intent is to “insure that the reliability of the message system as a whole is high, even though the reliability of transmission of individual symbols may be poor. Thus information theory has to do with a system in its totality. It takes into account possibilities, and a choice from among possibilities, and the freer the choice, the larger the amount of information will be. . . . The theory is not interested in what must happen, because information is the resolving of uncertainty, and unless uncertainty exists first, there can be no information. It is a theory of the nonsimple and the noncertain”(p. 254).

Information 2: Information as Object or Natural Resource

The second concept of information to be presented here is much more familiar in everyday terms than the more technical signal / channel concept outlined above. It can be considered to be today’s standard approach to understanding what information is. As is the case in all three of the concepts presented here, the information as object or resource concept is useful in summarizing a set of processes and relationships that people encounter in their ongoing activities.

This approach conceives information to be a kind of material object. This allows a versatile number of operations, activities and relationships to be included in one overall concept. When viewed in this way, information is considered to be a thing that can be obtained, stored, moved around, possessed like private property, and managed like public, common or natural resources. With the potential for becoming property, this view

of information supports efforts to control information through various forms of “intellectual property.” As a resource, information is thought to be amenable to management in ways that are similar to the management of natural resources such as air, water and open space.

In this aspect, information is thought to have independent existence, outside of the people who create and use it. It is thought to be capable of being “accessed” in a forms that embody universal meanings, useful for many people in many settings. This perspective is data- and document-centered. In it, there is no distinction maintained between the contents of databases and documents and information itself. Expressions about the value of information in this tangible form are often encountered, such as: “Information is a valuable commodity, and the seeking and retrieval of information have thus become critical activities in the Information Society. In a data-rich environment, access becomes the bottleneck in information processing” (Fabrikant & Buttenfield, 2001, p. 264).

This common understanding of information conceives it as being something to be found in reference books such as dictionaries and encyclopedias, and maps, or in places like libraries, doctors’ offices, newspapers and the World Wide Web. Dervin (1977, p. 18) whose perspective fits within the person-centered, or cognitive / constructivist concept of information elaborated below, says that the “collateral” that is “being exchanged in library service” is thought to be “information” and these premises “pervade Western civilization.” She says that there are assumptions that “there is some universal truth value about the user’s situation” and that “given enough information and given perfect retrieval of that information, every situation would have a perfect informational match” (p. 19). In this way our attention becomes preoccupied with “bigger and bigger storage and retrieval systems.”

As conceived in this way, information is thought to be closely involved with the process of transforming data, a low-value object, into knowledge, through a sort of refinement or value-adding process, always involving information objects of some sort. This process is described, for instance, by Cleveland (1985, p. 21) under the rubric “the knowledge dynamic,” where he asserts a progression involving “data, information, knowledge and wisdom.” Cleveland also cites what might be considered the “devolution” of information, as found in poet T.S. Eliot’s “Where is the wisdom we have lost in knowledge? Where is the knowledge we have lost in information?”

This data-knowledge spectrum, and problems with it, is also presented in Oettinger’s discussion of information as a resource base for “power in the 21st century.” “The term ‘information’ appears to cover too much that seems distinctive: knowledge, data, information in a narrow sense that some treat as synonymous with data, news, intelligence, and numerous other colloquial and specialized denotations and connotations. However, the distinctions implied by oppositions such as observations / theories, data / knowledge, raw intelligence / finished intelligence, accounting details / management information are secondary, not fundamental in characterizing information resources. They reflect only relative judgments. For instance, one person’s knowledge is often another’s raw data” (Oettinger, 1980, p. 193).

Cleveland explored the idea of treating information as resource, and identified some of the problems in this approach. In identifying the convergence of computers and telecommunications as defining aspects of an emerging information society, he claims that the “‘information society’ does not replace, it overlaps, the growing and extracting and processing and manufacturing and recycling and distribution and consumption of tangible things” (Cleveland, 1985b, p. 2). He reviews technical innovations of the 20th century, and claims that most innovations were “due to new knowledge or information. That makes clear the extent to which knowledge is an output or resource.” His core

question is presented, “If information (organized data, refined into knowledge and combined into wisdom) is now our ‘crucial resource,’ as Peter Drucker describes it, what does that portend for the future?” (p. 3). He recognizes that “this newly dominant resource is quite unlike the tangible things we have heretofore thought of as valuable resources. The differences help explain why we get into so much trouble trying to use for the management of information concepts that worked all right in understanding the management of things” (p. 2).

The difficulty of thinking about information in terms of being a public resource as a good comparable to other material commodities is detailed by Meyer. She discusses “the economics of information goods” in the following terms. “Pure public goods are both nonrival and nonexclusive, and thus information is an impure public good. While information is completely nonrival (to share information with an additional consumer imposes no cost on those already consuming it), the high costs of transmitting information mean that exclusion of persons from its benefits is possible. Information can be sold as a private good -- yet its benefits are not entirely appropriable either.” She continues by quoting Kenneth Arrow: “Information is inappropriable because an individual who has some can never lose it by transmitting it. . . . But then according to well-known principles of welfare economics, the inappropriability of a commodity means that its production will be far from optimal. It may be below optimal; it may also induce costly protective measures outside the usual property system” (Arrow, *Collected Papers*, Vol. 4, 1984, p. 142, as cited by Meyer, 1997, at p. 1129-1130).

These observations on information conceived as a commodity remind us of the “fictitious commodities” named by Karl Polanyi as being “land, labor and money” (K. Polanyi, 1944/1957, Ch. 6) as being integral to the “great transformation” brought about with the enclosure movement that marked the transition from rural agrarian society to urban industrialism. These fictitious commodities were the product of the ownership

classes that engineered this social transformation. The establishment of information as a resource commodity, as embedded in the present concept, may be the product of a similar concerted, though only partly conscious, effort.

The enclosure movement, and the loss of common property in land, has been noted in analogy to processes of exclusion related to information as object or resource, particularly through the rights assumed under intellectual property laws. Reconceiving information in terms of its being a common property resource has led to the metaphor of “information commons,” a concept that has been advanced by several authors; see (Agre, 1994; Felsenstein, 1993; Mosco, 1989; Onsrud, 1998; Schiller, 1996).

Much of the discussion by these authors is rooted in the information as object / information as natural resource concept, with reference to the difficulties of sustaining common property resources as identified by Hardin (1968). Problems and solutions are presented in terms of opening and assuring access to information resources by wider publics. They note stresses on our information environment that are parallel to stresses on the natural environment, and often identify public policies as being the essential factor in these processes. Mosco, in calling attention to the dangers of a “pay-per society” in which all information is clothed in microtransactional protocols, notes a persistent “growth of a movement to deregulate and privatize -- i.e., turn into market systems -- social institutions, including those chiefly responsible for communication and information. This contrasts sharply with an alternative policy principle: public policy made by representative bodies, not markets, should meet, not market needs, but the information needs of citizens who value information, and control over the instruments that produce and distribute it” (Mosco, 1989, p. 35). His recommendation is that we should begin with communication and information needs, not markets, and begin with an expanded notion of literacy.

Potential dangers that accompany the resource management concept of information are concisely summed up by Boyle (1996, p. E15), “We need to figure out how the world changes when information becomes one of the most important forms of wealth and power: When everything from the pattern of purchases revealed by credit card receipts to the pattern of your D.N.A. can become a byte of information, to be bought and sold in the marketplace. . . . We are in the middle of an information land grab and no one seems to have noticed.” Gary Marx’s suggestion (1997, p. 48) that the class of “information technologists and marketeers” who “all too often offer solutions in search of problems and substitute answers for questions” points toward the consequences of the dominant view of the object / resource concept. Information management, in this sense, can be seen as the base of a valuable center of profit, value and professional self-esteem.

An alternative framing of the commons of information scenario is suggested by Felsenstein (1993). His notion of “information commons” has less to do with common property and resource management, and is more in keeping with the idea of information as being involved in open public discourse. He asserts that all traditional societies, villages, are “centered around some space of assembly, which usually functions as a marketplace.” He calls the function of the village square the function of the “agora,” and suggests that the commons of information is “a way of interacting. It is not property” (p. 18). Connecting information with participatory process and public dialogue may help us to give attention to information in aspects that are distinct from the kinds of activity we expect when dealing with objects and material natural resources.

Felsenstein’s concepts help us bridge from the material to the cognitive view of information as outlined in the section below. If information here is considered as a natural resource object, in what follows (maintaining the resource perspective) it can be considered in human resource terms, in a human-centered rather than object-centered view.

Information 3: A Person-Centered or Social-Cognitive Approach

The third concept of information that is presented here can be thought of as a human-centered versus data-centered view outlined above. From this perspective, situated meanings are given equal importance to universals that are often required in the agreements and universal ontologies that characterize data-centered and information-as-object approaches. This view recognizes the importance of context as an essential element in determining information content, and sees the importance of connotative language as above denotative language, even when factual information is involved. It is in the tension between particulars and universals, globals and locals, that we find a basic polarity which affords choices for particular purposes.

In the present view, not only is the cognizing human being the user of information, but from this perspective information does not even exist until it is recognized and put to use by people. Information is intimately involved with living persons, their consciousness, purposes and actions. Whereas such notions as the transfer of knowledge, information flows, data warehouses, intellectual property, information economy and so forth fit well with the transmission and resource object views of information, they don't afford much room for creativity, the participation of the knower in what is known, the negotiation of meanings, or the importance of context in all communication and knowledge. Because this third concept is less familiar than the first two described above, and because it is the perspective that this thesis intends to strengthen, it will be elaborated in somewhat more detail here.

In this person-centered concept, each person is taken to be at the center of his or her own coordinate system. The phenomenological sociologist Alfred Schutz states the importance for each person of the "world within my reach," a person-centered coordinate system, the "center '0' of a system of coordinates which determines certain dimensions of orientation in the surrounding field and the distances and perspectives of

the objects therein . . .” (Schutz, 1967, p. 307). Liebman, an originator of the “social cartography” concept expresses it in this way: “Although each mapped community is self-central while spatially distanced and ideologically detached from other communities, the mappers’ world visions include specific core locations. . . . Simply stated, try as we may to expand our views of the universe, we still, as relativity theory argues, see all of space from where we stand -- the point in the whole of space that is the self” (Liebman, 1996, pp. 196-197).

This concept also adopts an action orientation to knowledge. In this view, people are essential participants in a creative process, they are sense-makers, information designers, negentropists, and these actions are necessary to their ongoing human existence. Information is less something to be collected, stored, managed, and bartered, but rather emerges, is relational, and comes into being and disappears depending on who is creating it, using it, and forgetting about it at any particular moment.

Integral to this action orientation are recognition of the motivations of individuals who are participating in information processes. Such concepts as attention, intention and commitment should have a place in our concept of information. The motivations and commitments of people, often neglected in information system design because of the difficulties in identifying, categorizing and measuring the wide ranges of factors that are involved, have the possibility of being recognized and included in systems that are designed around the requirements of individuals, who ideally are given full responsibility for the structure and contents of information environments related to their needs. This is the intent, in any case, of the design innovations that are offered later in this work.

In library and information science literature, the person who seems most closely allied with the third notion of information given here is the communications scholar Brenda Dervin, much of whose work centers on library settings. She calls her approach “sense-making,” which could easily characterize the concept discussed here as well as

person-centered or the more technically phrased cognitive / constructivist approach. Dervin asserts that because of pervasive “ontological chaos” there will always be an inability to “attain complete information,” leading her to speculate that it “may be more useful to conceptualize human beings as information designers rather than information seekers and finders” (Dervin, 1999, p. 41).

She also addresses the “transmission” image of information process directly, and contrasts it with “construction.” “Information is not seen as something that describes a given reality in an absolute and potentially accurate way, which can be transmitted from source to receiver through channels, which can be counted by external standards and pigeon-holed for all time. Rather, information is constructed. The act of constructing and the act of using that which is constructed is a qualitative act. It varies in kind” (Dervin, 1992, p. 81).

Winograd and Flores also question the transmission idea, linking it to rationalistic and representational traditions of thought. Their theory is based on the notion that “communication is not a process of transmitting information or symbols, but one of commitment and interpretation. A human society operates through the expression of requests and promises among its members. There is a systematic domain relevant to the structure of this network of commitments, a domain of ‘conversation for action’ that can be represented and manipulated in the computer” (Winograd & Flores, 1986, p. 176). They are deeply concerned “with the discourse and actions that are generated by a rationalistic interpretation of human action”, and know that “computer systems can easily reinforce this interpretation, and working with them can reinforce patterns of acting that are consistent with them” (p. 178).

Participation of individual human beings is intrinsic to Anthony Wilden’s definition of information. “Information may be symbolic, imaginary, or real and does depend for its existence on being perceived by living creatures or human minds or

senses” (Wilden, 1987, p. 76). He urges us to recognize “that matter-energy exists independently of its being perceived, but information does not” (p. 305). This “application of energy” is the core of the information act, and it is what distinguishes information processes from the causal processes of the (Newtonian) physical world. It fits with Newby’s “strong cognitive stance.” From this perspective, “information exists only if a change in knowledge state is brought about” (Newby, 1998, p. 8).

For Dervin, “information is conceptualized as that sense created at a specific moment in time-space by one or more humans. Information is not seen as something that exists apart from human behavioral activity. Because there is no direct observation of reality, all observations result from an application of energy by humans in one or more forms” (Dervin, 1992, p. 63).

There are frequent calls toward placing actual people at the center of information processes. Nardi and O’Day (1999) characterize particular people and particular roles as being “keystone species,” integral to their ecological view of information processes. They “are troubled when people ignore the human intentionality and accountability behind the use of technological tools” (p. 15). Grosser (1991, pp. 387-388) stresses the importance of human interaction in networks of information. He notes that information systems literature often focuses on “the physical nature of the information resource and its enabling technology” rather than on human dimensions. His review identifies “an overwhelming preference for human as opposed to document- or computer-based information sources” due to needs for social interaction, speed of interactions, ease, expertise, timeliness and the value that people add to information, “interpreting its meaning and significance in a particular context; this cannot be derived from documents or computer-based information sources.”

An example comes to mind from a group that seeks to improve regional information and data sharing. The originating meeting that launched the Gulf of Maine

Environmental Information Exchange was initiated with the phrase “people, people, people” as being what the systems being designed should be about (Farrey, Mooney-Seus, & Tausig, 1999). This perspective, or requirement, was maintained throughout the conversations that followed (Schroeder et al., 2001).

To say that “people” are the central organizing concept in the design and evaluation of information systems is not intended to imply that only people as individuals are involved in the concept. The present view of information, that also could be termed the cognitive / constructivist view, assumes no clear distinction between the individual person, that person’s motivations and perceptions, and the social and cultural context within which individual people are embedded. To say “people” are at the center could easily mean “people in communities,” another notion that is underrepresented in the realm of information systems design and evaluation (see Schroeder, 1999). To the extent this is a cognitive view, it should also be conceived as a social-cognitive view. This is the basic perspective of cognition given by Hutchins (1995) and Hall (1976). Hall’s focus is on cultural factors, and he criticizes current science that has a theory of mind separate from a theory of culture. “What has been thought of as mind is actually internalized culture” (p. 168). Sternberg, in presenting a “sociological metaphor” as a core metaphor of mind, describes the perspective of Lev Vygotsky, whose theory of “internalization” stresses the basic notion that “we observe those in the social environment around us acting in certain ways and we internalize their actions so that they become a part of ourselves” (Sternberg, 1990, p. 242).

The situatedness of information in cultural context also recalls the close relationship of space and time. This is recognized as a characteristic of the informal spatial reasoning explored by Egenhofer and Mark in their concept of naive geography (1995). They assert that “space and time are tightly coupled” and that many units in geographic space are linked to effort over time, including the acre, “based on the amount

of land that a person with a yoke of oxen or a horse can plow in one day or one morning,” as well as “similar measures for distance, such as how far a person can walk in an hour” (p. 8). The close relationship between space and time will be discussed further below in Chapter 3.

The perspective adopted here is represented in geographic information science by Couclelis’ definition of information: “Contrary to some common misconceptions, information is not a thing – i.e. a bunch of bits – but a relation between a sign and an intentionality: the sign(s) being, in this case, the various graphic and other forms of GIS output, and the intentionality, the purposeful human intelligence giving meaning to these signs” (Couclelis, 1999, p. 34-35). In another source she states that a “useful operational distinction between data and information is that data can be automatically manipulated and processed by a machine, whereas information presupposes the involvement of a cognitive agent . . . information (as opposed to data) is neither contained in, nor provided by, an information system independently of a cognitive agent who is both capable and willing to make sense of it. In semiotic terms, the diverse graphical, textual, numerical, etc. outputs of an information device form a system of signs that need to be purposefully deciphered for meaning” (Couclelis, 1998, p. 211). “Most importantly, information arises through someone recognizing it as such. . . . Information may not constitute knowledge, but it is closely related to it. Knowledge presupposes a knowing subject.”

A person-centered approach to information should acknowledge the importance of personal motivations such as the “commitment” recognized by Michael Polanyi in his theory of personal knowledge. He uses the expression “making sense” in the section on commitment (M. Polanyi, 1962). A commitment is “the general principle by which our beliefs are anchored in ourselves” (p. 59). Any method of knowledge, including scientific, includes informal suppositions, which come with “learning to speak of things in a certain language, in which there are names for various kinds of objects, names by

which objects can be classified, making such distinctions as between past and present, living and dead, healthy and sick, and thousands of others. Our language includes the numerals and the elements of geometry, and it refers in these terms to laws of nature whence we can pass on to the roots of these laws in scientific observations and experiments. . . . It is by his assimilation of the framework of science that the questions and commitments of scientists makes sense of experience. This making sense of experience is a skilful act which impresses the personal participation of the scientist on the resultant knowledge. It includes the skill of carrying out correctly the measurements which verify scientific predictions or the observations by which scientific classifications are applied. . . . The tracing of personal knowledge to its roots in the subsidiary awareness of our body as merged in our focal awareness of external objects, reveals not only the logical structure of personal knowledge but also its dynamic sources” (p. 60).

In a perspective from cartographic theory that is compatible with the approach in this section, MacEachren states, “The communication paradigm . . . floundered due to a fundamental assumption that matched only a small proportion of mapping situations: maps as primarily a ‘vehicle’ for transfer of information. A representational perspective, in contrast, begins with an assumption that the process of representation results in knowledge that did not exist prior to that representation; thus mapping and map use are processes of knowledge construction rather than transfer. To more fully understand how maps work, then, we must consider the ways in which mapmakers structure knowledge and the ways in which cognitive and social processes applied to the resulting cartographic representations restructure that knowledge and yield multiple alternative representations” (MacEachren, 1995, 459).

MacEachren’s recognizes the creative act of map making: “Maps are powerful tools, and have been for centuries, because they allow us to *see* a world that is too large and too complex to be seen directly. The representational nature of maps, however, is

often ignored – what we see when looking at a map is not the world, but an abstract representation that we find convenient to use in place of the world. When we build these abstract representations (either concrete ones in map form or cognitive ones prompted by maps) we are not *revealing* knowledge as much as we are *creating* it” (MacEachren, 1995, p. v). This perspective is directly connected to the approach to knowledge described in the section that follows.

A Note on Constructivist vs. Positivist Epistemology

The third approach to information, a person-centered or social/cognitive approach, can best be understood within an existing tradition of thought and work termed “constructivist epistemology.” Epistemology in general refers to formal theories about our ways of knowing, and constructivism places primary responsibility for knowing with the actively involved knower.

Constructivism, of which there are many varieties, can most easily be understood as being distinguished from the positivist and empiricist traditions. Positivism is defined as follows: “. . . systems of philosophy holding that theology and metaphysics belong to earlier or imperfect modes of knowledge whereas positive knowledge is based on natural phenomena and their spatio-temporal properties and invariant relations or upon facts as elaborated and verified by the methods of the empirical sciences” (Webster’s Third International, p. 1770). Empiricism asserts that “. . . knowledge depends ultimately on the use of the senses and on what is discovered through them” (Hamlyn, 1967, p. 499). Feigl describes the program of logical empiricism, which aims at universal formalization of language toward the orderly arrangement of the data of experience, a language “that would provide for the ‘unity of science’” He suggests that “the unity of the language of science simply amounted to asserting common, communicable perceptual experience to

be the ultimate testing ground for all sorts of factual knowledge claims” (Feigl, 1973, p. 548).

Entrikin notes that “scientific geography” always has a positivist orientation, even when subjective space is the object of study. This positivist approach is based on “empirical observation, public verifiability of conclusions, and the importance of isolating fact from value” (Entrikin, 1977, p. 210). Even behavioral geographers maintain “the existence of a ‘real,’ objective world and have considered man’s images of the world as deformations of reality” (p. 212). For instance, cognitive mapping as presented by Downs and Stea (1973, 10) is the process of “acquisition, amalgamation, and storage” of “information from a complex, uncertain, changing, and unpredictable source via a series of imperfect sensory modalities.” They ask, “How is information, derived from the absolute space of the environment in which we live, transformed into the relative spaces that determine our behavior?” (p. 12). They affiliate theirs with a program of developing “cumulative scientific knowledge” (p. 13).

In presenting a traditional model for perception and knowledge in terms of a spatial metaphor (and introducing two alternatives, one based in the work of Maturana and Varela, who are in the constructivist tradition) Fleischaker says the traditional model is grounded in Descartes, Locke, Kant and Helmholtz. “The traditional model is a causal one in which the properties of the external physical object affect the retina to generate an internal mental image of that object.” There is a distinction between sensation of the external world and perception in the internal world. Though the internal representation may be considered as does “Kant, that the internal representation has been actively assembled or, with Von Helmholtz, that it has been passively mirrored” they all maintain that “the external object and the internal representation are numerically and temporally distinct and that the internal representation is the end product of a causal and

unidirectional chain which starts with the external object” (Fleischaker, 1984, p. 41). The external world is thus the real world, and the internal world is its representation.

Roediger’s suggestion of “alternatives to the spatial metaphor” for memory (which is a composite of the characteristics of the object orientation to information and the conduit and pathway metaphors detailed below) relies on the “constructivist” approach of Neisser (Roediger, 1980, p. 239 ff.). He states that a “cognitive approach to memory and thought” implies that “our original perception of the world is a construction and that what we remember is the constructive act of the initial perception and comprehension.” On this point he quotes Neisser (1967, p. 285-286), “The present proposal is, therefore, that we store traces of earlier cognitive acts, not the products of those acts. The traces are not simply ‘revived’ or ‘reactivated’ in recall; instead, the stored fragments are used as information to support a new construction” (Roediger, 1980).

Von Glasersfeld observes that cognitive scientists generally distinguish themselves from behaviorists and other traditional approaches in terms of constructing versus receiving knowledge. “A genuinely constructivist theory of knowledge must deal not only with the process of cognitive construction but also with the relationship which the results of any such construction might have to the reality of the traditionally presumed ontological world” (von Glasersfeld, 1985, p. 92). He asserts a constructivist account of objectivity that is also “free from the traditional epistemological paradox” in these terms: “From that perspective, *objectivity* arises when concepts, relations and operations that I have found to be viable in the management of my own experience, turn out to be viable also when I attribute them to the models of Others which I construct to manage my interactions with them” (p. 99).

This circular process of interacting social relationships is part of what preserves the constructivist approach from being an expression of pure subjectivity. However,

moving away from a model of knowledge that depends on the existence of independent entities in the world, of which we have knowledge that is presumed to be verifiable, can involve disorientation. “Maybe one of the reasons why we avoid tapping the roots of our knowledge is that it gives us a slightly dizzy sensation due to the circularity entailed in using the instrument of analysis to analyze the instrument of analysis” (Maturana & Varela, 1987, p. 24). As Lehar puts it, “there is something deeply mysterious about consciousness, which is forever beyond our capacity to fully comprehend. As Searle (1992) explained, when we attempt to observe consciousness, we see nothing but whatever it is we are conscious of; there is no distinction between the observation and the thing observed” (Lehar, 2003, p. 3).

The paragraphs above represent an outline of the idea of constructivist epistemology in the present context. The works of a number of writers relied upon here indicate that their fundamental stance is in accord with a constructivist approach to knowledge, sometimes presented in somewhat different terms, such as Dervin’s “sense-making,” Reddy’s “radical subjectivity,” Newby’s “strong cognition,” and Maturana’s “autopoiesis.” Couclelis’ definition of information also fits: “Information is the relation that connects a sign with an intentionality. . . . Most importantly, information arises through someone recognizing it as such” (Couclelis, 1998, p. 211).

One additional concept should be introduced as being integral to the constructivist approach connected to the person-centered concept of information. This is “discontinuity.” Dervin provides the “core assumption on which sense-making rests -- the assumption of discontinuity. . . . This assumption proposes that discontinuity is a fundamental aspect of reality. It is assumed that there are discontinuities in all existence - - between entities (living and otherwise), between times, and between spaces. It is assumed that this discontinuity condition exists between reality and human sensors, between human sensors and the mind, between mind and tongue, between tongue and

message created, between message created and channel, between human at time one and human at time two, between human one at time one and human two at time one, between human and culture, between human and institution, between institution and institution, between nation and nation, and so on. Discontinuity is an assumed constant of nature generally and the human condition specifically” (Dervin, 1992, p. 62). She distinguishes her approach from the “radical constructivist” which she takes to be “no order out there or that there are no tools humans can use to arrive at more comprehensive and more stable pictures of that reality.” Rather, whatever order there is, is discontinuous; it is “not directly accessible by human observers,” and there is not assumed “an external standard to which they can turn for an assessment of their truth, either in an absolute or even a relative sense.”

A simple example of this situation of discontinuity, which I often characterize as there being “no inputs,” can be seen in the process of engaging in face-to-face discourse. Each person may have a large repertoire of sounds and gestures that are used to express meaning in direct conversation. Yet, in a very physical sense, there are “no inputs,” there is nothing but vibrations variously generated, sound and light wave forms, that then disturb or perturb the sensory apparatus of viewers and listeners – but there are no “gestures,” no “words” that actually pass from one person to the other. Jackendoff describes this in terms of the processes of vision. The brain does not interpret images because it does not see images. “When light strikes the eyes, the lenses focus it to produce images on the retinas. But nobody looks at those images either. Rather, the retinas convert the light into patterns of neural impulses, and it’s nothing but neural impulses from there on out” (Jackendoff, 1994, p. 172).

Seen from this standpoint, interpersonal communication has the character of performance, rather than as involving the transmission of objects, as we would expect from information theories based in the concepts of signals, channels, and information

objects. An understanding of the reality of discontinuity forms the basis for understanding the notion of person-centered information, and how it differs from traditional views that place information into an abstract interpersonal space rather than into the creative, constructive domain of human actions.

Summary of Three Concepts of Information

Three concepts of information have been reviewed here. The first appeared with the emergence of telecommunications technologies, and is part of the theoretical basis of the information sciences. The second reflects most people's everyday notion of information as something represented as an object (physical document or conceptual object) that exists as common property in the world, something that can be located, owned, and shared or not. The third is grounded in the actions of people, who create information through the choices they make, in an action orientation to information involving intentionality and other motivating forces, an ongoing "sense-making" that cannot itself make sense without the involvement of people as individuals or through their collective social institutions.

Brenda Dervin's work advocates for the grounding of library services in the sense-making approach speaks for an understanding of the third approach in library settings. She has described the standard questions about how to provide library services in the following terms. Librarians typically ask, "what information resources do citizens want?" and what are their "information needs?" However, these avoid more fundamental questions about what information is with customary answers: "Information describes reality. It reduces uncertainty and allows people to cope better. Information behaviors can be predicted on the basis of demographic attributes of people. Libraries can help by providing the 'right' information at the 'right' time. . . . The current view of information . . . is one that theoretically implies a view of the world as a place in which

there is complete order. Information is but a description of the order. To the extent that an order is not described, information is somehow missing and must be found.” She claims that this is a view of man as adapting to nature; but “man creates as well as adapts” (Dervin, 1977, p. 20-21).

The present work is intended to be situated in the tradition of Dervin’s view of information as expressed with co-author Patricia Dewdney in a later work (Dervin & Dewdney, 1986). “The picture of information that emerges . . . is fundamentally different from the more prevalent concept of it as a commodity: this postulates that information is an autonomous object that can be stored, accessed, and transferred. From the alternative perspective proposed here, information does not have an independent existence but is rather a construct of the user” (p. 507).

There is a fundamental tension among the concepts of information presented here. An adequate resolution is sought that will appropriately integrate the potentials of all three. The tension may be understood in terms of a two-sidedness in all objects and expressions, as expressed by the interpreter of indigenous architectures Suzanne Blier. For her these are expressed in “ontological” and “metaphorical” dimensions: “. . . the issues of ontological and metaphorical expression are central. Ontology, rooted in the reality of human existence, is contextualized in concrete experiences. . . . Metaphor also has basis in experience. . . . Ontology and metaphor thus are complementary aspects of an object’s (or idea’s or structure’s) significance. One conveys the reality defined in actual experience; the other extracts from this reality, transferring its meaning to other forms and ideas. Each complements the other in conveying meaning and symbolic intent” (pp. 1-2).

In a similar way, the various concepts of information may be read as manifestations of the ontological and the metaphorical aspects present in all expressions with significance. It seems that information must always involve two contradictory or

paradoxical aspects: the material, medium, object, documentary aspect; and the cognitive, interpretive aspect. Our task seems to be to recognize these as expressions of a unified whole in being and in process.

Keeping the whole in view is complicated by the difficulties in keeping the various senses of the word information straight, even among those who understand the distinctions at hand and want to preserve them. Couclelis, for instance, states that “information arises through someone recognizing it as such” and that “an information system thus neither contains nor provides information” (1998, p. 211). Yet her information spaces are populated with “information objects” and a transportation of objects model is inferred in sections devoted to information landscapes and information retrieval. In a similar way, Newby is sympathetic with what he terms the strong cognitive stance, creates a distinction between “cognitive space” and “information space,” but blurs the concept of information through discussion of “information objects” that “produce information” in users – providing us with two senses for information, one external in the object and one internal in the action of the user (Newby, 2001, p. 1021).

These are only mentioned in order to emphasize some of the difficulties of the task, which involves maintaining clear distinctions while using terms in which these distinctions are already blurred, sometimes intentionally serving particular interests and agendas (Poerksen, 1988/1995). Our formal definitions and customary word uses influence our conceptual structures, all of which help to determine the range of our customary or possible actions. Habitual speech obstructs alternative ways of thinking. By placing a focus on the sense-making approach to information, without excluding the possible benefits of employing the more familiar and accepted concepts, our intent is to increase available choices and range of actions.

Metaphors for Information Processes

This section presents three metaphors for information. The first, the “conduit” metaphor, was elaborated by Michael Reddy in a landmark study (Reddy, 1979/1993) in which the conduit image was linked to prevailing ideas of what happens in “communication.” The concern about communication, which was prominent in the decades before the 1970s when his essay appeared, has since then been replaced by a dominant discourse over the meanings of “information.” Reddy’s “conduit metaphor” is closely tied to a critique of the model for communication advanced by Shannon and Weaver, discussed above also in terms of the signal/channel concept of information.

The second metaphor for information presented here is termed the “pathways to knowledge” metaphor. This metaphor colors much of what is thought to be related to knowledge acquisition and problem solving. It has not been elaborated in any single source such as Reddy’s treatment of the conduit metaphor. In the information sciences, this metaphor is closely related to information “search and retrieval.” Here, discussion of this metaphor relies on the work of Lakoff and Johnson, particularly their identification of the source-path-goal schema as a fundamental construct of spatial relations in our thinking, emerging in various forms such as “achieving purposes” is “commonly conceptualized as reaching a destination” (Lakoff & Johnson, 1999, p. 517). They present this metaphor as being involved in all of our concepts of “means-end rationality . . . the choice of means for maximizing the achievement of purposes and minimizing unwanted outcomes.” For purposes of this paper, this process is considered to be closely related to question asking and answering, and problem solving in general, which are assumed to be centrally involved in information processes. As with Reddy’s conduit metaphor, the pathways-to-knowledge metaphor is closely tied to the two most commonly held concepts of information, the signal/channel and resource object views.

The third metaphor for information that is suggested here is termed the “resonance metaphor.” While expressions of resonance, reverberation, and similar terms appear occasionally in literature about cognition, learning, and communication generally, this aspect or quality of information processes has received little systematic treatment. As presented here, the resonance metaphor is proposed as a complement to the conduit and pathways images. In a sense, it is meant to add to our available repertoire of leading images about what information is, in order to overcome some of the conceptual limitations that are embedded in the other two. The resonance metaphor is intended to express the person-centered concept of information presented throughout this work.

The sections will outline these metaphors as they relate to information, and will explain how they may together afford a more comprehensive basis on which to base activities such as the design of information systems than is otherwise available to us.

Generative Metaphors

The importance of metaphors for our understanding of our world, and communication of that understanding, has been made clear through the work of George Lakoff and Mark Johnson and in works such as are collected in Andrew Ortony’s *Metaphor and Thought* (1979/1993). In their book *Metaphors We Live By*, Lakoff and Johnson (1980) present an example that might serve well in setting a conceptual frame for the ideas presented in this chapter.

In their example, Lakoff and Johnson outline for readers an “argument is war” metaphor, in which the language of war is shown to be present in most discussion about arguments between people generally. Included are such concepts as defeating, taking and defending of positions, winning and losing. Many of our responses to the activity of engaging in argument can be assigned to implications of the argument is war metaphor. This seems perfectly natural, given our cultural frame. Then they suggest the question,

how would arguments be different if another leading metaphor were involved? It is certainly hard for the reader to imagine an alternative, so they propose one: argument as dance, or performance. They provide a contrast to the argument as war metaphor through an hypothetical culture where “arguments are not viewed in terms of war, where no one wins or loses, where there is no sense of attacking or defending, gaining or losing ground. Imagine a culture where an argument is viewed as a dance, the participants are seen as performers, and the goal is to perform in a balanced and aesthetically pleasing way” (p. 5).

In a similar way, it is suggested here that our prevailing understanding of “information” is colored by leading metaphors that may limit choices available to us as we engage in activities such as asking questions, solving problems, and learning generally. Metaphors that in effect take over our conceptual choices, setting frames for our actions in ways that we are not fully aware, have been termed “generative metaphors” by Donald Schön. His essay on this subject immediately precedes Reddy’s on the conduit metaphor, in *Metaphor and Thought*, and Reddy refers directly to this concept as an indicator of the importance of that and similar studies.

Schön begins by stating that some authors seek to discount the importance of metaphor, considering it to be an “anomaly of language” and as something that is disruptive to the search for any “general theory of reference or meaning” (Schön, 1979, p. 254). He rather asks readers to consider metaphors as being central to all of our perspectives and frames, our “way of looking at things,” the “process by which new perspectives on the world come into existence.” He focuses particularly on the distinction between problem-setting and problem-solving approaches to policy making. In his terms, the making of social policy is usually considered as a problem-solving enterprise; he would rather give primary attention to the processes of “problem setting,” raising awareness of “the ways in which we frame the purposes to be achieved than with the

selection of optimal means for achieving them” (p. 255). This will bring our attention to the fact that we think in terms of generative metaphors and the analogies and “disanalogies” between familiar descriptions and the “actual problematic situations that confront us” (p. 255).

The outcome of this attention, he claims, is the possibility of what he calls “frame restructuring.” “There is a kind of cognitive work common to the integration of conflicting frames and to the making of generative metaphor, and to this shared process I have given the name ‘frame restructuring and frame coordination’” (p. 279). “In all of this, we need to ask what is involved in learning to do this kind of cognitive work? What is its relation, on the one hand, to domain-specific knowledge and, on the other hand, to very general sorts of competence in the use of language?” He also asks about “the conditions favorable to the practice of frame restructuring” (p. 280).

Much of the discussion below is intended to point toward a particular kind of frame restructuring that may be needed related to our ideas of information. The concept of “frames” is intrinsically spatial, and exploration of the meaning of spatial frames of reference in the work of Stephen Levinson (1996) and other authors will suggest the basis for the kind of shift in generative metaphor that Schön, Reddy and others have called for. The discussion below will examine spatial concepts that are intrinsic to these metaphors, toward frame restructuring for our overall understanding of information processes.

The Conduit Metaphor

Whereas Schön’s primary concerns were with the definition of social policy problems, and the ways in which generative metaphors might aid or stand in the way of policy problem solving, Michael Reddy took the perspective offered by Schön and turned it directly toward defining problems in language. He suggests that these problems of language are similar to the problems that Schön identifies, but replayed at a more

fundamental level, “several octaves lower” (Reddy, 1979/1993). We should note here that although Reddy in several places uses figurative language that intimates the “resonance metaphor” offered below (e.g. “several octaves lower”), he does not comment directly on these forms or their potential usefulness in solving the problems he surveys in his essay. Such terms and phrases as “right set of notes,” “long awaited music,” (p. 164) and “logical reverberations” (p. 170) appear in his discussion.

The importance of Reddy’s contribution was expressed by Lakoff in his essay on “contemporary theory of metaphor” that was in the second edition of the collection in which Reddy’s essay also appears. In a section titled “Homage to Reddy” Lakoff called Reddy’s a “now classic essay” that in a “single, thoroughly analyzed example . . . allowed us to see, albeit in a restricted domain, that ordinary everyday English is largely metaphorical, dispelling once and for all the traditional view that metaphor is primarily in the realm of poetic or ‘figurative’ language” (Lakoff, 1979/1993, pp. 203-204).

In Reddy’s view, “The problems of society, government, and culture depend ultimately on something like the daily box score of such successes or failures to communicate” (pp. 165-166) as were presented in Norbert Wiener’s concern about the “basic processes of human communication” in his book *The Human Uses of Human Beings*. Reddy identified Wiener as “one of the originators of information theory” (p. 164) and refers throughout to the theory of information and communication in terms of the conduit metaphor. Reddy’s analysis is made with a sense of urgency and commitment to change that makes it clear he does not look at our views of language, information and communication as of simply academic interest. To his readers he states an intent “to convince you of what may be a disturbing premise: that merely by opening our mouths and speaking English we can be drawn into a very real and serious frame conflict. My own belief is that this frame conflict has considerable impact on our social and cultural problems. If we are largely unable, despite the vast array of communications

technologies available to us today, to bring about substantive improvements in human communication, it may well be because this frame conflict has led us to attempt faulty solutions to the problem” (p. 165).

He continues by offering a personal account of how he came to a shift in his own frame restructuring, over several years “collecting some new facts and talking about them with many different people. Very slowly, during this period of time, these new facts initiated a frame change in my own thinking about language” (p. 166). Given an entirely new frame, he knows that describing it and getting acceptance from others will be difficult, since he found himself “speaking across the chasm of frame conflict.” In this way, Reddy lets his readers know that the attainment of a new frame is the result of a realization, a commitment and an effort, and invites them to begin to see the benefits that a similar reframing may have for them. We might note that the usage “chasm” as applied to human communication and understanding is spatial. This is similar to Brenda Dervin’s “gaps” that will be discussed in later sections (Dervin, 1992), and serves to alert us to the many ways in which spatial concepts are part of the frames and metaphors used when we are discussing aspects of communication and our information environment.

Given his commitment to the importance of his message, what are the characteristics of the “conduit metaphor” of communication? There are four categories that make up the “major framework” of this metaphor: “(1) language functions like a conduit, transferring thoughts bodily from one person to another; (2) in writing and speaking, people insert their thoughts or feelings in the words; (p. 3) words accomplish the transfer by containing the thoughts or feelings and conveying them to others; and (4) in listening or reading, people extract the thoughts and feelings once again from the words” (p. 170). Thus, words are containers that somehow are shipped among participants in communication, transferred via channels he calls conduits. This process also implies that thoughts and ideas somehow attain independent existence in an “idea

space” that lies external to people and that is without “any need for living human beings to think or feel them” (p. 170). Reddy makes it clear that a concept of communication that departs from human beings, via “reified thoughts and feelings” (p. 170) is not a suitable model. The resonance metaphor presented below intends to establish a base for understanding information from the perspective of the cognizing human subject, without which our concept of the information process is not complete.

Given the inadequacy of the conduit metaphor, Reddy suggests that “some alternate way of conceiving of human communication” is needed (p. 171) and presents an extended scenario that he calls the “toolmaker’s paradigm” as the expression of a possible alternative. The set of activities and relationships he proposes is complex, based on people who are thought to occupy nearby environments, similar to each other’s but not the same, and with no direct access across the boundaries that separate them. “Let us suppose that the people in these environments have learned how to . . . exchange crude sets of instructions with one another – instructions for making things helpful in surviving, such as tools, perhaps, or shelter, or foods, and the like. But there is, in this story, absolutely no way for the people to visit each other’s environments, or even to exchange samples of things they construct. This is crucial” (p. 172).

Again, this “absolutely no way . . . to visit . . . or even to exchange” is a theme that will be seen again in what is presented below in this work as a whole. Generally it will be identified with the word “discontinuity” or “discontinuities,” and the desirability of discontinuity rather than conceiving it as a problem to be solved. It is another facet of the information process that is embraced by Dervin in her “sense-making” view of information, a solution particularly designed for library environments that is firmly situated within the human-centered approach that is advocated here.

What is implied by this structure of discrete environments that Reddy asks us to imagine? It is that “people only know of one another’s existence indirectly, by a

cumulative series of inferences.” He calls this situation “the postulate of ‘radical subjectivity’” (p. 172), and it is clear that this intuition is an important element of the frame restructuring that Reddy himself underwent. Reddy then presents an analysis of the mathematical theory of communication and its base in the second law of thermodynamics, the natural increase of entropy, that “all forms of organization always decrease in time” (p. 175). In fact, “successful human communication involves an increase in organization, which cannot happen spontaneously or of its own accord.” In this way, human communication acts against the forces presumed by the second law. The force of human communication is that we always are applying energy to overcome the tendency to entropy. “Human communication will almost always go astray unless real energy is expended” (p. 174). It is this fact that points toward the central misconception perpetuated by the conduit metaphor, implicit in much of our ways of speaking about communication, in which processes of transmission seem to take care of outcomes that only the direct application of human energy can bring about. In Dervin’s terms, we are all and always “information designers” and it is from fundamental acknowledgement of that position that we should be interpreting the information process (Dervin, 1999).

The point of all this for Reddy was that if the “conduit metaphor is a real and powerful semantic structure in English, which can influence our thinking – then it follows that ‘common sense’ about language may be confused. I confess that it took nearly five years for me to come around to radical subjectivism as ‘common sense’” (pp. 175-176). It is an intention to support a general shift in “common sense” that Reddy achieved that motivates much of the presentation below, including the proposal of the resonance metaphor. He says that “no speaker of English, not even your author, has discarded the conduit metaphor” and that this will not happen “until we succeed in bringing about an entire series of linked changes in the English language” (p. 176). In this way, he is making an open appeal for change, not just in the way that we understand

our communication processes, but in the way that we actually act upon our understandings. He calls the hold of the conduit metaphor a “semantic pathology” that began with the serious problems that the originators of information theory, Shannon and Weaver brought about with how they “chose to name the parts of the paradigm.” The extension of information theory, in Shannon and Weaver’s terms, met with frequent failure. “I think that the reason for these failures was the interaction of the conduit metaphor with the conceptual foundations of information theory. As soon as people ventured away from the original, well-defined area of the mathematics, and were forced to rely more on ordinary language, the essential insight of information theory was muddled beyond repair” (p. 182).

As example, Reddy looks at the term “message” as used in Shannon and Weaver, and as understood in everyday speech. A message can be both a set of signals, as in “I got your message, but had no time to read it,” and as the alternative states represented by the signals among which choices must be made in interpretation, as “I get the message, let’s leave him alone” (p. 183). For Reddy, since the theory is based on the notion that the second kind of message is never sent anywhere, whereas the first is, “this choice of words leads to the collapse of the paradigm.” If the originators had taken more care, they would have more clearly distinguished between the different messages, with different terms. However, in Reddy’s view, they could not have taken this care, since “their thought processes were responding to the biasing effect of the conduit metaphor.” He quotes Weaver directly: “How precisely do the transmitted symbols *convey* the desired meaning?” (italics Reddy’s) and discussion of two “messages, one of which is *heavily loaded with meaning* and the other of which is pure nonsense” (emphasis Weaver’s, p. 184). Further confusions about the function of the signals in the theory, that they “do something” (afford the “power to reproduce an organization by means of nonrandom selections”) while also speaking as if they “contain” something (p. 184).

At the end of his extended analysis, Reddy claims that these fundamental confusions about what is happening in the communication process causes us to neglect the responsibility of participants in the communications process, and to avoid the real work that must be done (p. 185). The conduit metaphor, pervasive in our ways of speaking, helps us to believe that communication is a “success without effort” system when in fact “energy must be expended.” When we begin to believe that information has to do with the creation of, transfer and storage of more and more signals, we “neglect the crucial human ability to reconstruct thought patterns on the basis of signals and this ability founders” (p. 188).

The final extended example that Reddy offers is to apply these considerations to the common understanding of what a library is. He dismantles the assumption that ideas are in libraries by analyzing a “chain of metonymies” that involves our thinking that ideas are in words, and words are on pages, and pages are in books, and books are in libraries, thus ideas may be found in libraries. Reframed, however, “there are of course no ideas in the words, and therefore none in any books, nor on any tapes or records. There are no ideas whatsoever in any libraries. All that is stored in any of these places are odd little patterns of marks or bumps or magnetized particles capable of creating odd patterns of noise. Now, if a human being comes along who is capable of using these marks or sounds as instructions, then this human being may assemble within his head some patterns of thought or feeling or perception which resemble those of intelligent humans no longer living. But this is a difficult task . . .” (p. 187). In fact ideas and culture are not in documents and libraries, and there “is no culture at all unless it is reconstructed carefully and painstakingly in living brains of each new generation. All that is preserved in libraries is the mere opportunity to perform this reconstruction.”

Another observer (Von Foerster, 1980) called attention to the distinction between the documents and their arrangement in a library and the “information” they are thought

to contain in terms similar to Reddy's. He wrote, "Nevertheless, since we think we know what information is, we believe we can compress it, process it, chop it up. We believe information can even be stored and then, later on, retrieved: witness the library, which is commonly regarded as an information storage and retrieval system. In this, however, we are mistaken. A library may store books, microfiches, documents, films, slides, and catalogues, but it cannot store information. One can turn a library upside down: no information will come out. The only way one can obtain information from a library is to *look* at those books, microfiches, documents, slides, etc. One might as well speak of a garage as a storage and retrieval system for transportation. In both instances a potential vehicle (for transportation or for information) is confused with the thing it does only when someone makes it do it. *Someone* has to do it. *It* does not do anything" (p. 19).

Von Foerster also provides the humorous and memorable image of the "Nuremberg Funnel," a caricature of the conduit metaphor. "I always believed that thinking of knowledge as packagable, transmittable, marketable commodity was a recent perversion until I ran into a broadsheet printed in the late 16th century that dramatically depicts an elementary educational situation. A young lad, apparently a student, is seated on a chair and has a funnel inserted through a hole into his head. Next to him stands a teacher with a bucket full of knowledge which he is in the process of pouring through the funnel into the student's head. A few letters, numerals and a simple equation are seen just falling from the bucket." Von Foerster suggests that this pedagogical method is still with us, "funnel-aided instruction" (Von Foerster, 1982, p. 279). After discussion of the many implications of this prevailing view, he continues "I hope it is sufficiently clear that teaching via the Nuremberg Funnel would not work, not because of the funnel, but because of the bucket – it won't hold knowledge" (p. 281). A contemporary illustration

by Peter Bennett that is reminiscent of the Funnel is reproduced here (Figure 2). It originally appeared as an untitled illustration for an article by Lawrence Lessig on regulating the Internet (Lessig, 2000, p. 27).

Reddy's concerns about the dominance of the conduit metaphor in our thinking about communication and information processes generally are reflected in the motivations for the present work. The search for an alternative metaphor begins with the understanding that information does not exist apart from the cognizing human subject. Also, that there are inevitable discontinuities that are not flaws in our systems of information relations, but that must be recognized and built into the systems we design for managing our interactions including communication. Finally, the notion that "conduits" actually connect, that messages actually travel, that ideas can pass from one place and person to another work against recognition of actual discontinuities in information processes. The section that follows, discussion of the "pathways" metaphor, will address this point in more detail.

The Pathways Metaphor

This section outlines a second metaphor for information processes, most commonly conceived as the process by which we go about "acquiring" knowledge. There is a sense in which the pathways metaphor can be seen as a reversal of the conduit metaphor. Instead of considering information, or knowledge in its material aspect, to be embedded in objects that somehow move, are transferred or transmitted to the person who needs them in some form, this metaphor implies that it is the seeker who moves from one place to another, from a place characterized by uncertainty, to a place where knowledge in some form is found.



Figure 2. Illustration by Peter Bennett. This can be viewed as a contemporary rendering of the Nuremberg Funnel. (Reproduced by permission, see Appendix B)

That the “pathways to knowledge” formula is well established is shown in the over 1,500 results returned from a Web search for the phrase (though reduced to under 50 when limited by including the word “metaphor” in the query). An example of the metaphor’s use, with a positive connotation, is found in an online document devoted to adult learning: “The ‘Web’ as metaphor is meant to conjure a positive image: multiple strands of interlocking information that users can traverse as easily and as delicately as a spider negotiates a web’s dewy filaments. For the adult learner, however, the World Wide Web can seem more like an impenetrable maze than a set of linked pathways to knowledge” (Literacy Assistance Center, 2000).

I have not found a thorough study of the pathways metaphor comparable with Reddy’s treatment of the conduit metaphor. Reddy worked from a deep personal conviction that the conduit metaphor holds a power over our thinking about knowledge, memory and cognitive process generally that needed to be questioned and ultimately undone. The conduit metaphor does seem to be more pervasive, and less benign, than the pathways-to-knowledge metaphor.

Discussion of the pathway metaphor will be briefer, and sources more various, than the discussion based on Reddy’s work presented above. The intention here is not to dismantle the pathways metaphor, as to understand its workings in a way that may show the potentials and problems of adopting a pathway view in any particular informational situation.

There is a pattern of everyday activities that gives credence to this metaphor. For instance, when we are looking for something that is lost, we will often move from place to place in search for it. We know that we have left these things “somewhere,” and the task is to imagine and then traverse paths from where we are (and they are not) to the places where they are. The process is both a cognitive process, involving memory and

speculative thought, and a physical process, movement across distances from points of origins to destinations that are our goals.

This may suggest criteria for design of information spaces, based on factors of manipulability as discussed later in this paper. The actuality of paths from the unknown to the certain, as expressed in our everyday actions, suggest that problems with this metaphor are not as significant as those identified by Reddy in the case of the conduit.

Nevertheless, the use of this metaphor in some sense disables our understanding of what is involved when we are engaged in other common information-related activities such as searching the World Wide Web. It is customary to use phrases such as “go to” and “I went” when describing the action of traversing such a space. “I went to their site and got . . .” a web document. Yet, of course, I did not go anywhere. I tapped some keys, moved a mouse, clicked on some “buttons” – and sent a signal to a machine in another place, that was able to recognize it as such and decode it, and to then undertake internal operations that resulted in the sending of a string of digits streaming in return, decoded locally and displayed on my own local machine.

What do we mean when we say that we have “gone somewhere” in this way? In this case, our going and coming back represents a change of state in the machine that is in front of us. Changes of state seem to be a common condition covered by the pathway metaphor. There seems to be some limitation in our ability to speak directly about state changes that leads to the adoption of a metaphor such as this.

This aspect is made explicit in the work of Canter, Rivers and Storrs on characterizing “user navigation through complex data structures” (1985). After stating that their work involves an “attempt to capture some of the psychologically significant aspects of the movement of users within interactive data-bases” (p. 93) – taken literally this would make for an interesting trip – and claiming to study “the actual *route* taken through the data” (p. 94), they state their central claim: “Moving from one place to

another is akin to interacting with a computer system in order to change its state. The state changes possible within the systems are analogous to the places accessible from each other” (p. 94). It is only along the way that we learn in passing that these constructs are “analogies” (p. 94), but soon again the authors begin to speak of as “journeys” through data structures.

The essential point here is not that these aren’t “really” journeys, or that we as database users do not actually travel through structures of data. Rather, something about behavior in this situation is like taking a journey. What is actually happening is that the machine and the user go through a series of state changes, that in some sense are analogous to making a journey. Canter and colleagues then present a plausible typology of state changes in terms of the order in which various states are achieved. They rely on Alty’s “path algebras” in which “finite state systems are characterized as a connected graph whose arcs are the transitions between states” (p. 94). These are then classed as various forms of loops, rings and spikes, in the form of the resulting graphs, and correlated with searching behavior that they call searching, scanning, browsing, exploring, and wandering – each appropriate for particular people, in particular settings, toward particular goals, and serving different cognitive styles. “It is easy to imagine two expert users with different characteristics, one methodical in his approach to work, the other more erratic and inspirational. While both might be successful in achieving their aims within a data-base / expert system, it is likely that they would be more effective if operating in a software environment that was more sympathetic to their individual styles” (p. 101). These point toward a need to design robust interfaces that might allow people choices among these strategies, and that help people understand their “routes” to desired data results, while helping them not to get lost in the process.

Their results are closely reflected in Newby’s presentation of “navigation” as a search model, before this took hold as a standard metaphor for interaction with the World

Wide Web. “Instead of considering the organization of the database and the design of the interface separately, they are considered together: functionality of the system and the access mechanisms to that functionality are inseparable. . . . As one can navigate more easily through a familiar physical space, a closer match between user and system information space will allow for easier and surer wayfinding. . . . The notion of a document having some relevance value independent of a user is not accepted. System information spaces might have different meanings for different users” (Newby, 1991, p. 112).

Lakoff and Johnson’s discussion about “mathematizing means-end rationality through metaphor” helps us to generalize the navigation approach of Canter and colleagues, and Newby to other patterns of action. Their basic idea is simple. Given desires and purposes, as well as results we may find undesirable, by means of the application of reason, the problem is set as to how to “choose to act most efficiently and effectively to maximize achieving your desires and purposes while minimizing unwanted outcomes?” (p. 517). They find that “achieving purposes is most commonly conceptualized as reaching a destination, via the Event-Structure metaphor. . . . In that metaphor, actors are conceptualized as travelers and courses of action as paths that lead to destinations. An action is motion along a path. The state resulting from an action is a location. The choice among actions is the choice among paths. The Event-Structure metaphor has the effect of spatializing action to achieve a purpose as motion to reach a destination. This is the first metaphorical step in the mathematization of achieving purposes” (Lakoff & Johnson, 1999, p. 518).

They then relate this spatialization of purposeful action to the image of branching trees, often used to visualize decision points. “The next step is to take our spatialization in terms of locations and paths to other locations and visualize it metaphorically as a ‘tree,’ with the initial location as the ‘root,’ the trunk and branches as the paths, and the

branching points as intersections of paths -- places where one must make a decision as to which way to go.” These are visualized as points and directed lines, the form of “decision trees” (p. 518).

Note that they, like Canter and colleagues, refer to the concept of changes in “state” as part of this metaphor: “The state resulting from an action is a location.” We are reminded that as we traverse a physical path, such as in hiking a mountain path, we will mark our progress (and attain our purposes) by pauses at vistas sequentially attained. Traversing a path is to have accomplished an ordered visibility; as we move we attain ordered views. This may be the way that the pathway metaphor, though literally not true, may be put to best use in interface design. Pathways in digital environments have more the character of sequential viewing than movement as such.

This orderliness is a form of constraint, and thinking of pathways in terms of established constraints may help in seeing their value. Providing paths constrains movement, to the benefit of the person in traverse (protecting from dangers off the path, for one) and in protecting the environment traversed. Constrained pathways may help the person in creating order, focusing attention, achieving goals by means that would be unmanageable or unthinkable without established paths.

Given this overview, the task for the system designer seems to be similar to the process followed by Canter and colleagues. That is, to spatialize a process that is intrinsically not spatial, by metaphoric means that bring parts of the metaphoric source to bear aspects of the problem at hand. Requirements for paths in digital environments may include characteristics from physical paths across terrain: they should be well marked, be continuous integral and whole, and be traversible in reverse.

It should be remembered that the path itself, in many cases, is of importance equal to the destination when learning processes are underway. Knowing “how we got here” and not just where we are is an important aspect of Web browsing that is not well

supported, but that is wanted in many cases. The notion of paths as “trails” that have intrinsic value and that should be preserved within the record of any search was intrinsic to the design concept put forward by Vannevar Bush in his “memex.” The searcher “builds a trail of his interest through the maze of materials available to him. And his trails do not fade.” In his conceptual scheme, it is the availability of a set of trails that have been established that allows the inquirer / researcher to find resources, and then to make them available to others (Bush, 1945, p. 107). A contemporary statement, related to geographic approaches to information access, observes: “Similar to footprints in the sand, information seekers may leave search trails behind when browsing an information space. These search trajectories relate to query histories in traditional information retrieval. Information items might be repositioned on or off the ‘beaten track’ for faster discovery or later retrieval” (Fabrikant & Bittenfield, 2001, p. 269).

The paragraphs above have shown how the pathways metaphor is grounded in actual human activities such as searching for lost objects (often involving kinesthetic knowledge, as described in more detail in Chapter 4 below) and translating the traversal of a path involving sequential attainment of vistas or views, into creating order in viewing successive states of a machine or of a person’s interaction with a machine. These are useful in conceiving of effective organization of machine interfaces for human “navigation.”

There are, however, activities that are part of general information processes that may not be well served by the pathways-to-knowledge metaphor. These may include the questioning and answering process. No doubt, often this process is embedded in an environment that requires actions that are like traversing paths. The answering of a question at a library reference desk often results in the patron (and sometimes the librarian) traversing a path from the place where the question is asked and negotiated, to the place where an answer is found. Of course, this takes the motivational background of

the patron as given (often unexplored in customary practice of reference service; see (Dewdney & Michell, 1997)), and is fully grounded in the concepts of information that situate it among shared universals, and as seen as object and resource. As was argued in the section on person-centered or cognitive / constructivist concepts of information, practices that serve one set of concepts, images or metaphors may not be effective when other aspects might better be emphasized.

The transmission and object concepts of information, and the conduit and pathways metaphors, all involve movement in some form, the movement of information as object or the movement of person as involved in search and retrieval activities.

Lakoff examines metaphors for time in detail, and his conclusions point toward why we can easily see information in terms of objects. “It has often been noted that time in English is conceptualized in terms of space. . . . Time is understood in terms of things (that is, entities and locations) and motion” (Lakoff, 1979/1993, p. 216). Lakoff states that the “present time is at the same location as a canonical observer” and then outlines in detail the mapping of the metaphor “Time Passing is Motion” (p. 217). There is an “object/location duality” (p. 225). In terms of time, it can be “understood in terms of relative motion between an observer and a time. In the object-dual, the observer is fixed and times are moving objects. In the location-dual, the opposite is true. The observer moves and times are fixed locations in a landscape. . . . In addition, the object in motion is conceptualized as a possession and the thing-changing as a possessor. Change is thus seen as the acquisition or loss of an object. Causation is seen as giving or taking” (p. 225). Thus, if we conceive of information as involving change, by Lakoff’s metaphoric analysis, there can easily be expressions that implicate information processes in the giving or loss of objects, even though no object is actually involved in the process.

Are the established concepts and metaphors adequate to a situation in which it might be established that nothing moves? We have shown an example earlier, in that the

online searcher does not really “go anywhere” when browsing the Web. The notion of movement would be minimal if we were to take seriously the central notion of “discontinuity” that is part of Dervin’s “sense-making” – there may be no way to get from here to there, and there may be no way to bring it to us, whatever “it” is, and whatever is presumed to be “there.”

Another problem in the question asking and answering process that may not be fully served by the pathway metaphor is the actuality of multiple strategies of approach to a question, multiple satisficing answers, and fundamental changes in the question being asked due to the iterative nature of the process. Within the pathways metaphor, we might say there are “multiple paths to multiple destinations,” not all of which are recognized as candidate destinations before the search is underway. This fundamental uncertainty could be represented by multiple branching trees. This is the extension of the pathways metaphor suggested by Lakoff and Johnson and mentioned above (Lakoff & Johnson, 1999, p. 518). This is also recognized by Canter, Rivers and Storrs in one of their classes of search, “wandering.”

This wandering among uncertainties leads to the notion of browsing, and even the “serendipity” of finding, discussed within *New Directions Downeast* as an important outcome of effective digital library design (New Directions Downeast, 2002). Chang and Rice (1993) in their discussion of browsing posit two “basic wayfinding learning processes [which] operate simultaneously: non-dimensional and dimensional learning,” the first of which generates “sequential or route maps and suggests a linear design style for a wayfinding system” while the second generates “a spatial or cognitive map and encourages a spatial design style” (p. 248).

Although Chang and Rice do not elaborate on the distinctions between what they term sequential and spatial design styles, it is suggested here that a spatial approach involving discrete (discontinuous) structures may serve as an alternative to the concepts

and metaphors for information that involve movement and transportation, such as we find in the pathways to knowledge metaphor. Their distinction of sequential vs. spatial approaches recalls an early work in the field of search and retrieval that outlines many aspects of the approach that is elaborated here. Doyle's "semantic road maps for literature searchers" (1961), after detailing several then-current competing approaches to document classification in terms of new machine capabilities, asserts the importance of giving structure, the constraints provided to assist searchers. He says it "is probably psychologically sound to give a literature searcher some kind of a structure, whether hierarchical or otherwise, rather than to give him an infinitely flexible and therefore totally disorganized array of terms" (p. 570). "Two kinds of structures can be envisioned at this point, hierarchical and associative" (p. 571). He suggests that "association maps" actually could be drawn by the searcher. "A psychological association map would result if some eager human decided to organize in detail all knowledge. Such a psychological association map would also result if all literature searchers were asked to draw a small map of the associations which lead to their search request statements (in using a system such as coordination indexing) and all these small maps integrated to form a big one" (p. 571).

His "two kinds of structures" seem essentially to be Chang and Rice's "linear and spatial design styles." Considering how alternatives may be imagined to the prevailing metaphors and design approaches will be explored in the concluding section of this chapter.

Imagining and Adopting Alternative Metaphors

Benking and Judge (1994) call for the development of repertoires of spatial metaphors that may be suitable for interface design. They suggest the "interesting possibility, that some complex systems may only be adequately comprehended through

three or more complementary metaphors” (at p. 2 of 5). This call for an expanded repertoire of metaphors reflects Schön’s attention to the importance of “generative metaphors” in framing policy problems (Schön, 1979). Kuhn suggests that appropriate metaphors can be selected and designed to meet the needs of users in particular task environments, including in the operation of computer interfaces (Kuhn, 1993).

In the course of his analysis of the conduit metaphor, Reddy began to imagine an alternative in the form of a “toolmaker’s paradigm,” but the scenario he suggested seems to be much too complex and detailed to become the basis for a commonly held metaphor for information and communication processes.

Increasing our repertoire of metaphors suggests that we allow an opportunity for new structures to be created and brought into relationship with those that already exist. The basic insight of Carroll and Thomas (1982) is that cognitive learning involves adoption of new “structures,” and that this learning comes about through metaphor: “People develop new cognitive structures by using metaphors to cognitive structures they have already learned” (p. 109).

The range of available alternative metaphors for memory in natural language is presented by Roediger. He states that metaphors are often used “when confronted with a phenomenon that we do not understand, to try to relate it to things that we do understand or at least are more familiar with” (Roediger, 1980, p. 231). In his survey of metaphors for memory he begins with a review of Julian Jaynes’ observation that consciousness and mind are generally conceived in terms of “metaphor of an actual physical space, with memories and ideas as objects in the space” (Jaynes, *Origin of Consciousness*, (1976), 48-66; cited by Roediger at p. 232). He continues by noting that we speak of our ideas in terms that would be appropriate for objects in space, “allow room for new ideas” or see them as being “bright, dim, hazy or fuzzy” (p. 232). Of 36 examples given in his Table 1 (p. 233), 27 are designated as being either “spatial analogies with search” or “other

spatial theories.” Nine are put in a third catch-all category, “other analogies.” He states that there now is “no other general conception of the mind or memory” that rivals “the conception of the mind as a mental space in which memories are stored and then retrieved” (p. 238).

Even though the storage metaphor has become pervasive, it shouldn’t be taken to imply that our brains manage memory in that way. Roediger reviews a number of results that potentially “embarrass the spatial storage and search assumptions” (p. 238). Even though alternative conceptualizations might be available, “the spatial storage and search assumptions are so ingrained in our language that [establishing alternatives] may be difficult” (p. 239). Among alternative candidates, he refers to the ideas of Bartlett (1932) and Neisser (1967) who propose the notion that “remembering involves a construction of memories from available information, rather than a verbatim reproduction of the contents of memory” (p. 239).

To accompany the concept of constructing memory Roediger presents three analogies “based one way or another on auditory imagery” (p. 240). Though one of these, the signal detection analogy, is often integrated into the concept of spatial search processes, there is a distinct alternative: the “resonance or broadcast metaphor” (p. 241). Citing Edwin Boring, he recounts a tradition going back to David Hartley’s (17th c.) concept of “vibratiuncles,” the “physiological counterpart of ideas” (*History of Experimental Psychology*, 1950, p. 196, cited at 241). A more contemporary expression is also cited, D.B. Wechsler’s, “Memories, like perceptions and eventually sensations, have no separate existences. . . . Memories are not like filed letters stored in cabinets or unhung paintings in the basement of a museum. Rather, they are like melodies realized by striking the keys on a piano. Ideas are no more stored in the brain than melodies in the keys of a piano” (“Engrams, Memory Storage and Mnemonic Coding,” *Am. Psychologist* 18, 1963, pp. 150-151, cited by Roediger at p. 241).

Roediger states that the “same basic idea of retrieval as a matching or resonance process has been used by a number of other psychologists.” For some, retrieval is compared to “the operation of a tuning fork. When a tone of a particular frequency is sounded in the presence of a bank of different-sized tuning forks, the appropriate one will vibrate sympathetically” (p. 241). In everyday speech, we might say that an expression we have heard, sometimes in reply to a query, “rings a bell.” Roediger observes that resonance models may be “formally identical to spatial storage and search theories if one assumes an unlimited capacity, parallel search process” (p. 241). The final alternative to spatial metaphors outlined by Roediger is Pribram’s holographic, or optical filter, analogy.

Roediger’s presentation of several metaphors for memory that are based in auditory or resonance images points toward the “resonance metaphor,” discussed in detail below in Chapter 7. Also, his use of words such as bright, dim, hazy and fuzzy point toward the “pools of light” metaphor suggested by a pattern in Alexander and colleagues’ approach to architectural design (Alexander et al., 1977, p. 1160). In his summary, Roediger observes that the preponderance of spatial search metaphors may be limiting to the development of “psychological theories and models of memory,” and that “the construction, levels-of-processing, and resonance metaphors” may be helpful (p. 244). Since many of the spatial search metaphors derive from “the technology of keeping records,” he sees an opening through new technologies for the development of alternative metaphors of memory and mind. Certainly the alternatives that are suggested below depend on new technologies, both to represent structures and to link them.

In attempting to conceive of alternatives to the pathways-to-knowledge metaphor, we may begin with the concept of fields. An association between pathways and fields is suggested by Murray, who describes Koffka’s “valence field theory of navigation,” which follows discussion of more customary idea of navigation as being decision

making, the “form of discrete decisions” being likened to choice of paths. Such choices are exclusive or “bistable” such as found in Necker cubes, since once choice excludes others. However, “the perceived paths themselves, and the perceived promise and risk of each path” are expressed as “fieldlike entities in the brain” (Murray, 1995, p. 227).

Murray also recounts Gibson and Crooks’ (1938) proposal of a “field theory model of driving,” that also might apply to perceptual behavior while walking (p. 228). He says that the abstract thinking required for long distance navigation also involves fields, that an abstract “thought cloud” (p. 230) may be available mentally, able to rotate, be scaled, reoriented, etc, similar to the reading of a map.

The pathways-to-knowledge metaphor probably understates the complexity and variety of paths followed in any instance. In practice, most pathways are found to be very indirect and crooked; there is no assurance that the most direct path imagined at the outset of any undertaking will be the most effective route to the goal. Social barriers are inevitable, and since knowledge is socially and culturally based, these blockages must be part of any model of knowledge relationships and production. This is where an alternative structure, still pathlike in some respects, becomes available, the domain of “small world” effects. The small world model is a dual structure: ties that are locally strong and globally weak, relating dense clusters of strong relationships through important but rare and somewhat random distant ties (Buchanan, 2002, p. 207). A small world model seems to fit the concept of federated workspaces that is described below as an alternative to the pathway paradigm.

The small worlds concept also affords a means of overcoming or circumventing the pervasive in-group / out-group distinction in social realms. Often the most basic decision that is made in the evaluation of information is to determine whether the source belongs to an accepted, or an outsider, social realm. This pattern of human behavior won’t be overcome through the design of information systems, but appropriate design

may help to mitigate its effects. Systems need to allow connections that are not straight-line, strong-link. If crooked loops are found to connect people, a system's design should afford something of the same indirect character, which would represent another departure from the pathways metaphor.

The alternative metaphor that is suggested in this work, the resonance metaphor for information, will be described in detail in Chapter 7. One other metaphor that is briefly mentioned in several places here is "pools of light." As was the case with the resonance metaphor, pools of light was first suggested in discussions centering on the graphic *This Corner of the World* (Figure 1) especially in terms of the end-nodes of the three branching trees that are included in that visualization, but that have not yet been incorporated into the heuristic workspace. "Pools of light" is Pattern 252 in *A Pattern Language* (Alexander et al., 1977, p. 1160) and Hunting makes reference to this in his New Directions white paper (Hunting, 2002). Alexander and colleagues state that "it is a fact of human nature that the space we use as social space is in part defined by light" (p. 1161). Within New Directions, discussion of the "pools of light" metaphor centered on how someone, traversing a discontinuous treelike network, might be made aware of resources at a distance, but not accessible by direct path from that network explorer's standpoint.

Boas, in his essay "Idea," notes that etymologically the word idea "is related to the verbs 'to see' and 'to know'" and that the "notion that ideas can be apprehended by a kind of vision or intuition, by looking and seeing them, has never been lost in Occidental philosophy, for knowing as a kind of insight, illumination, revelation has almost always been retained" (Boas, 1973, p. 542). Lakoff and Johnson affirm this, observing that "understanding is seeing; ideas are light-sources; discourse is a light-medium" (Lakoff & Johnson, 1980, p. 48) and note in a later work that "*illuminate*, an extended instance of the general Knowing Is Seeing metaphor, is learned well after the conceptual primary

metaphor “Knowing is Seeing is learned” (Lakoff & Johnson, 1999, p. 490). Further exploration of how variants of the “pools of light” metaphor might be useful in constructing alternatives in information system design remains a task for future work.

That the resonance metaphor has been adopted here should not imply that the pathway and conduit metaphors are intended to be totally overturned or rejected. They clearly speak for many of the elements experienced in information processes. For instance, the idea of movement, intrinsic to both standard metaphors, has a place in several of the theories that seem quite appropriate in terms of information processes. Dervin, who works from within the constructivist frame, include the notion of movement in their metaphoric notions of “gaps,” “steps” and “situation stops” (Dervin, 1992, p. 75). Krippendorff (2002) suggests that the “ability to move” is intrinsic to the concept of space, including social spaces such as the conversation spaces he explores. To choose among metaphors, and the adoption of nonconventional metaphors toward expanding choices, is ultimately a pragmatic decision that can only be evaluated through the consequences of the choice in practice.

While there are many similarities across the concepts and metaphors for information that have been presented in this chapter, there is no direct mapping between the three concepts and the three metaphors. Rather, the concepts are directed toward understanding how information is thought to work from several perspectives, and the metaphors are vehicles for generalizing the concepts according to patterns of understanding that are applied in many domains.

The constructivist or “strong cognitive” approach advanced here reflects that of Von Foerster: “For if indeed we have to abandon the notion of a commodity called ‘information’ which changes hands in a process called ‘communication,’ then we must also abandon a strategy that keeps us searching among things outside of us and adopt one that allows us to look for processes within ourselves” (Von Foerster, 1980, p. 21).

It is in these terms that new models and metaphors are being explored here. For instance, rather than assume that searchers travel toward answers or that answers can be packaged for delivery upon request (a model that works for many purposes), a set of mutually related question spaces is proposed in which questions (and questioners) are brought into closer proximity, and through these mutual proximities answers may gravitate toward questioners. The end product does not aim to attach an existing answer to an emerging question, but aims rather to create a new entity, the answer to the new question, as something new that can serve both as question and answer in the next iteration.

These are some of the considerations that motivate our attention to alternative metaphors such as resonance and pools of light, and the ideas that are intended to be realized in the heuristic workspace presented below.

Chapter 3

CONCEPTS OF SPACE: SPATIAL VOCABULARIES AND FRAMES OF REFERENCE

Introduction to Concepts of Space

An inquiry into spatial aspects of information sharing processes, where this study began, requires a general reflection on the question, “What is space?” This chapter reviews some of the answers to this question that have been given by geographers and others involved in the tradition of inquiry now adopted by the spatial information sciences. Whereas the present inquiry began in an attempt to inventory spatial concepts as expressed in specific words, phrases, and terminology in general, toward creating order among spatial concepts, the availability of frames of reference and coordinate systems turned out to be more useful than was a catalog of the range of available spatial terms. This chapter reviews approaches to defining “space” generally, outlines the collection of spatial terms that were gathered as candidate codes for qualitative text analysis, and gives an overview of spatial frames of reference in everyday language. Because all of language is culturally rooted, including concepts related to frames of reference, this section at times refers to cultural aspects that are further discussed in the next chapter.

Because space is a general quality that pervades all of human experience, not just in its physical aspects, and not just as metaphoric extensions from a physical ground, defining space in concise or universal terms is particularly difficult. Couclelis and Gale outline the range of domains in which concepts of space are situated: “subjective or objective, psychological or mathematical, relative or absolute, empirical or formal, Euclidean or non-Euclidean, metric or non-metric . . .” (1986, 1). Miller and Johnson-Laird emphasize the pervasiveness of space through a quotation from Wilbur Urban’s

Language and Reality (1939, p. 186) that “our intellect is primarily fitted to deal with space and moves most easily in this medium. Thus language itself becomes spatialized, and in so far as reality is represented by language, reality tends to be spatialized” (Miller & Johnson-Laird, 1976, p. 375). Given this range, there should be no surprise that definition is difficult.

Couclelis and Gale (1986) begin to resolve this diversity and the ambiguities it involves through defining space with the “most general mathematical definition of space available,” from Alexandroff: “The concept of topological space is only one link in the chain of abstract space constructions which forms an indispensable part of all modern geometric thought. All these constructions are based on a common conception of *space* which amounts to considering one or more systems of objects -- points, lines, etc. -- together with systems of axioms describing the relations between these objects. Moreover, this idea of a space depends only on these relations and not on the nature of the respective objects” (pp. 4-5).

The definition of space given by Golledge and Hubert is similar (1982). Space is “an *abstract set* possessing a topology. Given such a definition, one can expect that the space is a set over which concepts of continuity and proximity may be given meaning” (p. 108). Both of these general definitions emphasize relationships and rules. Alexandroff’s explicitly, in “systems of axioms describing the relations between . . . objects” and Golledge and Hubert’s in terms of relationships that can be established, specifically the relations of “continuity and proximity.”

That space involves relations rather than objects, and that there are sets of rules that apply for any given space, seem to provide a workable base from which to think about “spatiality” in general. The notion of “spaces” occurs in many contexts in everyday English: decision spaces, information spaces, conversation spaces; geographic space, the space of geospatial data, cyberspace, question space, and so forth. It seems essential to

ask, when considering any space, what rules hold for it (or “in” it) and what relationships are established by means of those rules.

Turnbull quotes Piaget in emphasizing the pervasiveness of space in our experience, that “spatiality is fundamental to our consciousness and our understanding of experience.” It is fundamental in “ordering our knowledge of the world.” He also cites Malcolm Lewis’ point that spatial concepts help to “provide the structural as well as the functional foundations of language” (Turnbull, 1993, pp. 1, 2). These remarks emphasize the bridge from our assumptions about space as conceived in the character of our physical surroundings, toward acknowledging the integral relationship between human agency and perception and our concepts of space.

Further clouding the boundaries of the concept of space is its close relationship with time. Space and time, which are often taken as being two distinct dimensions of existence or of the order of the world, seem to be more intimately connected than is generally sensed in their everyday expression. The Oxford English Dictionary is organized around historical usage, with historic first occurrences taken from written documentary sources. In the OED, five double-column pages are devoted to the word “space.” It first appeared in English at about 1300 A.D. In the definition for its first historical usage, space denoted “time or duration”; when used without an article, space meant “lapse or extent of time between two definite points, events, etc., chiefly with adjectives such as little, long, short, small” (p. 87). Two columns of text are devoted to variants of the word space as meaning what we would generally call time, until the fifth definition is reached: linear distance; interval between two or more points or objects. This, our everyday notion of “space” first appeared about 1390; the example provided is “Astronomie . . . makth a man have knowechinge Of Sterres. . . . And what betwen hem is of space.” The OED’s Definition 6 provides, “Superficial extent or area; also, extent in three dimensions” which only is documented beginning at 1387; example given for this is

“Also Affrica in his kynde hath lasse space.” Thus, definitions of space in the sense of distances, areas and dimensions in the physical world are documented nearly a century after uses relating mainly to time (Oxford English Dictionary, 1989, p. 87).

Of course, in everyday speech as opposed to printed sources our sense of space may have been prevalent, or may have come first but not be documented. What this history suggests, however, is that “space” and “time” are intimately involved with each other; that we separate them at some risk; and that the concept of space/time as a unified whole is quite intelligible in everyday usage. Some contemporary writers have taken the opportunity to express this relationship concretely, as in Bakhtin’s “chronotope” said by Entrikin to capture “the sense of space-time wholes that have fascinated both geographers and historians” (Entrikin, 1991, note 23, p. 139).

Space has been defined by geographers generally in terms of the character, extent or scale of our physical surroundings. A recurring distinction is asserted between large and small scale space, sometimes called table-top space vs. geographic space, or perceptual space vs. transperceptual space. Freundsuh and Egenhofer (1997) attempt to characterize such spaces in a unified continuity with portions distinguished in terms of “manipulability, locomotion, and size of space.” They suggest “six types of spaces” termed manipulable object space, non-manipulable object space, environmental space, geographic space, panoramic space, and map space. They suggest that these categories will be of help in developing a coherent concept of a naive geography, “a set of theories of how people intuitively or spontaneously conceptualize geographic space and time” (p. 1). The notion of manipulability is discussed below in Chapter 4, as an important factor in peoples’ knowledge generally and in terms of the design of informational, conceptual or knowledge spaces.

Robinson and Petchenik’s review of the concept of space asserts that “the map *is* space” (emphasis in original) (1976, p. 86). Map viewers will have reactions to “map

space,” and this will be a “function of fundamental concepts of space.” They discuss the work of Piaget (as do Mark and Frank, below) in terms of such fundamental concepts as proximity, separation, enclosure, spatial order and symmetry. These are linked to “representational space” (p. 88), of which map space is one version.

Mark and Frank (1996, p. 10 of 23) refer to Piaget and Inhelder’s concept of perceptual and transperceptual space; these concepts are also cited by Downs and Stea (1977, p. 197). Mark and Frank emphasize how our bodies influence spatial perception, beginning with one of the most salient factors, gravity, the up/down axis. They discuss Kuipers’ views on how we negotiate large scale space, via landmarks, views, etc. They provide extensive discussion of what may be required to coordinate these spaces, toward finding geometrical ways of representing natural language spatial understandings.

Entrikin, in reviewing the distinction between empirical and phenomenological geography, presents Kant’s notion of space. “Kant viewed space and time as types of intuition which provide form to the manifold of sensation. Through the spatial intuition of the perceiver, experience of the external world gains its form. Space is thus imposed by the perceiver on perception rather than being derived from perception by the perceiver” (Entrikin, 1977, p. 215). Translating from Kant, Entrikin states that space is the “form of possible objects.”

Entrikin notes that Cassirer extends Kant’s notion of spatial intuition, toward its being a “feature of all human experience” including myth, religion and science (p. 216). Cassirer claimed that there are three modes of human knowing, the affective/emotive, the intuitive and the conceptual. The first manifests in art, religion and myth; the second in language and the “natural world of common sense,” and the third in mathematics and science (p. 217). “Each spatial mode is part of a symbolic system, and no modality of space represents a mere replication of some outer reality. Rather, each modality serves a formative function in organizing man’s experience. Space, like time, is an a priori set of

relations imposed by consciousness on experience and is necessarily found in the variety of symbolic systems” (p. 217). Entrikin states that the “objective world becomes intelligible to language to the degree in which language was able, as it were, to retranslate it back into terms of space” (p. 218). Thus, space becomes an organizing principle within which all of human experience becomes intelligible, and that “the various systems of knowledge created by man have distinct spatial perspectives, and that it is important to understand each spatial perspective in terms of the symbolic system of which it is a part” (p. 219). It should be noted that Entrikin’s narrative seems compatible with the overall view of coexistence of simultaneous frames, within one existential field, a perspective that is compatible with the approach that is adopted in the present work.

Entrikin’s reference to Kant’s view of space as the “shape of possible objects” may have a bearing on the notion of forces, structures and forms as presented in Chapter 5 below. The notion of possible objects also suggests a nondeterministic world, such as one in which space is related to our ability to make choices. The concepts of space and information both seem to share in being about our abilities to make choices and have some relationship to environments for the emergence of the new. This is seen, for instance, in the “room to move” that is central to Krippendorff’s “conversation space” (2002). This suggests that a fundamental positive human activity is in helping to make space for others, suggesting an approach to the ethics of social space. Further discussion of space in human dimension will be presented in the next chapter.

A final concept should be added to these overall considerations about space. Space does not simply exist, in fixed quantity and form, to be populated or filled but otherwise unavailable to human agency. Rather space is *created*, not simply there to be occupied. We accept the view of Lefebvre, who states that “social relations of production have a social existence to the extent that they have a spatial existence; they project themselves into a space, becoming inscribed there, and in the process producing that

space itself” (Lefebvre, 1974/1991, p. 129). In this way we may begin to see ourselves as being capable of generating totally new spaces that are not competitive with existing space, allowing people to engage in the process of creating and negotiating new worlds.

Spatial Terminology

A collection of spatial terms was created as part of codebook development for purposes of analyzing interview data texts. The goal was, and still is, to consider how information sharing processes are expressed in spatial terms. In exploring code candidates, no inventory or thesaurus devoted to “spatial concepts” was found. Rather, suggestions for core spatial terminology were found embedded in many sources where many discrete sets of terms and concepts were found. See Appendix A: Spatial Terms from Codebook 3 for a list of terms that were candidates for data text coding.

Resources that were consulted in establishing a core spatial vocabulary included controlled vocabularies such as the *Library of Congress Subject Headings* and the thesaurus of the *Geographical Index*, collections such as Buck’s synonyms in the Indo-European languages (Buck, 1949), as well as a range of writers in geography, spatial information sciences and related disciplines: (Bloom, Peterson, Nadel, & Garrett, 1996; Buttimer & Seamon, 1980; Couclelis, 1992, 1998; Freundsuh & Egenhofer, 1997; Gollidge, 1995; Levinson, 1996; Miller & Johnson-Laird, 1976; Talmy, 2000a; Tversky, 1996; Vatsyayan, 1991).

This collection of over a hundred terms as candidates for a “spatial” vocabulary made it apparent that spatial terminology is pervasive in our language. Hall came to a similar conclusion through an informal investigation of his own. He examined the pocket Oxford dictionary, looking for “all terms referring to space, or having spatial connotations, such as: together, distant, over, under, away from, linked, enclosed, room, wander, fell, level, upright, adjacent, congruent, and so on. A preliminary listing uncovered close to five thousand terms that could be classified as referring to space. This

is *20 per cent* of the words listed in the pocket Oxford dictionary. Even deep familiarity with my own culture had not prepared me for this discovery” (Hall, 1966/1969, p. 93).

Golledge (2002) notes that lack of a “widely accepted vocabulary” for spatial concepts inhibits the discipline of geography. He raises the question of how “we build primitives and low order concepts into more highly ordered (complex) terms.” The spatial primitives he suggests include “place-specific identity, location, magnitude, time, boundary, and distance” (p. 7). From these may be derived distribution or arrangement of objects, regions, frames of reference, orientation and directions, spatial hierarchies; and at higher orders, patterns, clustering and dispersion, etc. In an earlier article, Golledge suggested that the primitives of spatial knowledge are “identity, location, magnitude, and time” (Golledge, 1995, p. 29). Identity means to establish identity of place or phenomena in space, often through labeling and naming. Local conditions make universal identification difficult. Magnitude means “how much” in all dimensions. After defining the “primitives,” he suggests derived concepts such as distance, angle and direction, sequence and order, connection and linkage (pp. 33-35). Then he gives examples of spatial distributions and 2-D phenomena such as boundary, density, dispersion, pattern and shape (pp. 35-37) followed by the “higher order” derived concepts of correlation, overlay, network, and hierarchy (pp. 38-41). Concluding his review, he raises many questions about how the various understandings of these concepts cause difficulties for users of GIS and other systems designed and intended for use by “experts” (p. 43) and with the “type of error that is carried along as baggage with every spatial concept that we use.” Following Golledge, Fabrikant and Buttenfield (2001) list “key spatial concepts” as being identity, location, direction, distance, magnitude, scale, and time or change. In terms of information visualization, “Each has a parallel in the spatialized transformation of semantic content” (p. 268).

The very partial attempt to inventory spatial terms, toward coding text segments for expressions of space while discussing information processes, confirmed a growing sense of the all-pervasive nature of space in all of human experience. Because the same terms might be used when discussing the physical geographic world, and the human-centered social-cognitive world, some strategy for distinguishing uses of spatial terms in very different contexts seemed necessary before any identification of spatial concepts through spatial words, or vocabulary, would be feasible. The survey of concepts of space provided a means of distinguishing spatial concepts in terms of their settings, suggesting connotative and contextual approaches to spatial concepts rather than denotative, literalist approaches. A resolution was found in the form of spatial “frames of reference,” explored by many researchers into the relationship between language and space.

Spatial Frames of Reference

The idea of spatial frames of reference can easily be approached through a story told by William James. For him, the following story was meant to illustrate the meaning of pragmatism. He recounts returning to camp after a day of hiking, and finding a raging controversy among his fellow campers. The debate centered on a squirrel on a tree trunk, and on a person who tried without success to see the squirrel, who kept moving around the tree. The question at issue was: “Does the man go round the squirrel or not? He does go round the tree, sure enough, and the squirrel is on the tree; but does he go round the squirrel?” (James, 1987, p. 505). James’ solution followed “the scholastic adage that whenever you meet a contradiction you must make a distinction. . . . ‘Which party is right,’ I said, ‘depends on what you *practically mean* by “going round” the squirrel.’ If one means passing through the cardinal directions about the squirrel, then ‘obviously the man does go round him,’ for he occupies these successive positions. But if on the contrary you mean being first in front of him, then on the right of him, then behind him,

then on his left, and finally in front again, it is quite as obvious that the man fails to go round him. . . . Make the distinction, and there is no occasion for any farther dispute.”

Establishing frames of reference as a way of orienting our speaking about spatial relations is a prerequisite for understanding the relations we are indicating. This section will present a few examples from authors who have attempted to define what frames of reference are required for reducing ambiguity in expressing spatial relations. The choice and use of linguistic frames of reference also is similar to the kinds of decisions that are made in establishing figure and ground as are presented by Gestalt psychologists in illustrating the processes of human perception. The discussion of frames of reference will conclude with a description of the three-frame scheme provided by Levinson and his colleagues: intrinsic, relative, and absolute. These provide a sufficient and useful means of distinguishing among possible approaches to defining frames of reference.

One of the problems in learning about frames of reference is that most of the discussion has been in technical terms that are not part of everyday speech, thus undermining the usefulness of analyses that are meant to describe what are for us very common everyday practices. The approaches of three authors to the linguistic expression of spatial frames of reference are given in essays collected in a single volume edited by Bloom and colleagues, *Language and Space* (1996).

Framing expressions about spatial relationships in everyday speech begins with the act of perspective taking. Levelt (1996) says that perspective taking is part of the “microplanning” of conversation, and is “a process of abstracting spatial relations for expression in language” (pp. 77-78). He proposes three frames, or choices for perspective taking: deictic (a speaker-centered relative system), intrinsic (expressing the position of a referent in terms that are intrinsic to a reference object) and absolute (such as cardinal directions). The term “deictic” often also appears in related literature as “deixis,” or sometimes as the more familiar-sounding “indexicality.” The word “deictic” refers to a

showing or pointing out directly; for instance, “the words this, that, and those have a deictic function” (Merriam-Webster Inc., 2003). The word “index” also refers to pointing. Indexical expressions are relative, not absolute, in that they depend on distinctions drawn among referents in the immediate, shared environment of those in discourse. Levelt concludes that there are no “fixed laws,” no “hard-wired” mappings that guide the choices of perspective as expressed in language. “There are preferences, for sure, following Gestalt properties of the scene, human interest, and so on, but they are no more than preferences.” Choices depend on culture, “communicative intention and situation” (pp.102-103). He also states that the frames given by Levinson and colleagues would also be sufficient for his own purposes.

A different set of frames is suggested by Tversky (1996), who reviews such areas as object recognition, which can be viewer-centered or object-centered (p. 464); environmental perception, where the pertinent concepts are egocentric and allocentric, “a reference system external to the environment, usually the canonical axes, north-south, east-west” (p. 465); or perception organized according to landmarks. She notes that neurophysiologists suggest “three bases for spatial reference systems: the viewer, landmarks, and an external reference frame” (p. 465). She emphasizes peoples’ ability to “take perspectives not currently their own” and that there are “three bases for spatial reference: the viewer, other objects, and external sources. . . . These three bases at first seem to correspond to deictic, intrinsic, and extrinsic uses of language, though it will turn out not to be that simple” (p. 465). She distinguishes intrinsic and extrinsic within the deictic approach, intrinsic using properties or sides of the reference object, while extrinsic requires reference to the speaker’s frame (p. 466). She then relates these approaches to Levinson’s scheme of relative, intrinsic and absolute (p. 467). The absolute is a form of extrinsic, and Tversky notes that Levinson says that two of the frames,

intrinsic and absolute, are “binary, that is, they require two terms to specify the location of the target object: the target object and the referent object.”

Levinson, who is involved in an ongoing cross-cultural study of expressions of spatial relationships in language, has identified three frames of reference that are available in our culture. At least two of the three appear to be available in all cultures (though not always the same two). The author claims that “there is a cross-modal tendency for the same frame of reference to be employed in language tasks, recall and recognition memory tasks, inference tasks, imagistic reasoning tasks, and even unconscious gesture. This suggests that the underlying representation systems that drive all these capacities and modalities have adopted the same frame of reference” (Levinson, 1996, p. 109). In a later paper, Levinson and colleagues state that “different languages induce distinct conceptual codings” in the spatial domain, and that “language and conceptual coding in the spatial domain covary” (Levinson, Kita, Haun, & Rasch, 2002, p. 155). In spite of the finding that there is “in fact a great deal of cross-cultural variation in the semantic relations and categories of spatial language” (p. 156) and that though “not all languages make use of all frames of reference” (p. 183) the basic three frames of absolute, intrinsic and relative account for the available frames in all cultures. This conclusion is limited to manipulation of objects and their relationships in tabletop spaces, the experimental setting devised for these investigations.

Pederson and colleagues, including Levinson (Pederson et al., 1998) have undertaken an extensive “crosslinguistic and crosscultural study of spatial reference” (p. 556). Whereas they found that the three basic frames of reference can account for all spatial framing in language, all three frames may not be actually used by some cultures, and cultures may have very different means of expressing these frames. They found that “what one language does with a dedicated morpheme, another language might express with a construction and/or pragmatic rules. Accordingly, in order to allow for broad scale

comparison of languages, our level of comparison can be neither morphemes nor lexical items. Rather, our level of crosslinguistic comparison must be contextually interpreted utterances” (p. 565). They did find that half the languages in their study used both relative and absolute frames; but in some these just provide information about the participant and not the geography, or in others they provide information that is “geo-cardinal and never about a speech participant” (p. 572). “Communities differ in dramatic ways with respect to spatial reference in language. Importantly, we find that the human body is by no means a universal template for creating projective coordinate systems for spatial reference in tabletop space” (p. 584). They found “linguistic relativity effects” and assume that such mechanisms “would potentially operate across many areas of human cognition.” They surmise that these language structures are not just available, but that the linguistic system “actually forces the speaker to make computations he or she might otherwise not make. . . . That is, the linguistic system is far more than just an *available* pattern for creating internal representations: to learn to speak a language successfully *requires* speakers to develop an appropriate mental representation which is then available for nonlinguistic purposes” (p. 586).

Talmy (2000b, p. 230 ff.) also addresses the individual / cultural components of frames available in speech. He presents schemas and schematizations of space – somewhat like frames – and asserts that the speaker chooses among those available. Reviewing these choices, “it is the speaker that selects one schema over another from those available and applicable, and it is thus the speaker that determines the highlighting of one group of factors or of another.” and that culture and language “preselect” among alternatives.

Just as people must choose among terms when speaking, they also must choose among frames in pre-organization of expressions. Fabrikant and Bittenfield (2001) review how small and large scale environments are understood by means of gaze views,

routes or tours, putting relative, intrinsic and extrinsic frames of reference to use, which “can be switched frequently, and the choice is thought to be dependent on the type of environment and how the environment has been experienced -- for example, by navigation or by map reading” (pp. 269-270).

The complexities of reference frames are again apparent in Klatzky’s discussion of allocentric locational, egocentric locational and allocentric heading representations in context of “whole-body navigation” as contrasted with settings involving manipulation of objects (1998, p. 3). Another set of considerations involved in choice of a frame of reference, or the “transformation from a visual perception to the relative expression of reference frames” is said by Frank to involve an origin (speaker, object, another person), an orientation (“e.g. the axial frame of the speakers, of the addressee, or another object” and “handedness of the coordinate system (same as a person’s or inverse)” (1998, p. 293).

Reviewing the literature of spatial frames of reference, Levinson (1996) notes major categorical distinctions involving relative vs. absolute, egocentric vs. allocentric, viewer-centered vs. object-centered, orientation-bound vs. orientation-free, deictic vs. intrinsic, and viewer-centered vs. object-centered vs. environment-centered. He then provides a basic definition of Gestalt as “a unit or organization of units that collectively serve to identify a coordinate system with respect to which certain properties of objects, including the phenomenal self, are gauged” (p. 126). His discussion concludes with “three linguistic frames of reference,” (p. 138) intrinsic, relative, absolute.

In his Fig. 4.9 (p. 139) Levinson provides a helpful graphic description of what these frames mean by means of “canonical examples of the three linguistic frames of reference.” For intrinsic: “He’s in front of the house;” the reference point of origin is a house, with its parts labeled. For relative: “He’s to the left of the house;” the reference point of origin defines left in terms of the location of the observer. For absolute: “He’s

north of the house;” the origin is at the house, with reference frame composed of the cardinal directions.

After discussion of this model, he notes another problem: the “three distinct frames of reference are ‘untranslatable’ from one to the other, throwing further doubt on the idea of correlations and correspondences across sensory and conceptual representational levels” (p. 152). At this point he introduces Molyneux’s Question: “If a blind man, who knew by touch the difference between a cube and a sphere, had his sight restored, would he recognize the selfsame objects under his new perceptual modality or not?” His conclusion: “In short, either the frame of reference must be the same across all sensory modalities to allow the cross-modal sharing of information or each modality must allow more than one frame of reference” (p. 156). Since frames are not translatable, individuals are required to “stabilize their representational systems within a limited set of frames of reference.”

Levinson also notes the importance of perspective taking, of expressing spatial frames of reference, as part of the work needed in overcoming the underdetermined nature of all symbolic expressions, both visual and verbal. Levelt draws our attention to “ellipses in spatial expressions” (1996, p. 95), the parts of scenes or spatial relations that are left out of descriptions. The importance of underdetermination in symbolic expression is discussed in greater detail in the next chapter.

An overall conclusion that may be drawn from the discussion above is that before any vocabulary or terms can be defined within a particular instance or use of spatial terminology, the range of available frames of reference that is appropriate for that particular context or communicative intent (such as our interest in expressing perceptions about information sharing) needs to be seen in terms of choices among available options. While there is a large vocabulary available for speaking about spatial relations, frames of reference provide a syntax for this, and suggest the contextual cues for interpretation and

interrelation of terms, providing a ground for these terms' meanings in particular relationships.

Summary: Concepts of Space

The concept “space” seems at first to be unproblematic. Space has the character of openness, a expansive uniformity throughout. Space seems able of being displaced by objects that occupy it without diminishment of its essential character or quantity. Space in this sense mainly characterizes the physical world external to human beings. We have become accustomed to the idea of an infinite physical universe, or one whose boundaries are at best indefinite, a Newtonian concept of absolute space (Curry, 1996, p. 92). Space is conceived as a sort of container without walls – within which everything, somehow, finds a place to be, either through the order of nature, an Aristotelian view, or through some set of social decisions or agreements.

This unproblematic space works well enough in default applications for everyday life, but its pervasive acceptance may obscure the availability of alternative concepts. We have seen that space is found to afford several different conceptualizations, leading to the conclusion that more than one space may be found to simultaneously coexist on mutual terms. Our common notions of space may not yet be inclusive enough to allow the variations that in fact already exist to be put to their full potentials in use.

Attempting to create a collection of concepts related to space began with a question that has been part of the basis of this work throughout, the intuition that there may be spatial aspects to the activity we call information sharing. Is there a spatiality to our information processes? Before interview data could be coded to signal the occurrence of spatial concepts as expressed in language, toward substantiating a spatial component for general understanding of the information sharing process, some sense of the range of what spatiality might mean was found to be needed. Many terms indicating spatial

relations were collected, but the words themselves are of limited value in text analysis without a better understanding of the frames of reference that help give meaning to their use in particular contexts. The coding of text would need to take account of these linguistic frames in addition to the use of particular spatial terms.

While trying to sort out the framework for the use of a spatial vocabulary, it also became clear that some other distinctions may be as problematic as the concept of space itself. It was the task of sorting out spatial terminology – actually, the discovery of its pervasiveness through all of human experience as made clear through examining spatial vocabulary – that certain other distinctions became less clear than they might seem in unexamined everyday speech. First, the distinction between individual cognition and social process is difficult to maintain, as many authors emphasize in their assertions that individual cognition is embedded in social process. Thus the term social-cognitive seemed to be an appropriate reframing of cognitive processes. In a similar way, literature about aspects of individual cognition that depend on physical embodiment, the direct physical interaction of the individual with a physical world, along with the notion that even our physical spaces are largely the expression of human activity, suggest a blurring of the distinction between the physical / geographic and the social-cognitive dimensions.

All of these dimensions are simultaneously implicated with each other, and are not as distinct as we often would think. The distinctions we draw out of convenience may mask the usefulness of thinking about all of these aspects as being parts of a unified whole. These realizations led to a sense that a most fruitful approach might be to assume that our lived space is one field that includes the geophysical and sociocognitive at once, and to assume that spatiality pervades this field in all aspects. From this perspective, the various dimensions of lived space might have the possibility of being represented within a single coordinate system (probably involving multiple origins in individuals and communities), within which multiple frames of reference may be simultaneously

available. In this view, one domain such as the social-cognitive would not occupy a space assumed to be based metaphorically upon a more real geophysical space. Rather, space would be seen to involve all of human experience, each dimension of which may be represented through simultaneous coordination rather than by means of literal or metaphoric translations from one domain to another. Finding a way to coordinate such multiple co-existing spatial frames thus became part of the problem that is set for this work.

These multiple frames may be seen as the dimensions within a single coordinate system, each dimension expressing the particular rules and relationships that apply in each dimension. We are accustomed to thinking that we live in a three dimensional world. If this is so, what are these dimensions? Most familiar, and most tied to the geophysical world at all scales from tabletop to geographic, are the three dimensions of physical space: height, depth and breadth, with a “fourth dimension” of time added in. As we have already seen, the time dimension can as little be unraveled from space as can our bodies be separated from the physical world, or our individual selves from the social contexts within which we exist.

The anthropologist Edward T. Hall posited that there is a “hidden dimension” within which we live, the dimension of culture. He called the science of relationship between space and culture “proxemics,” and thought that raising awareness of the cultural basis of spatial relations was essential, for “no matter how hard man tried it is impossible for him to divest himself of his own culture, for it has penetrated to the roots of his nervous system and determines how he perceives the world.” This is “a new dimension – *the cultural dimension* – most of which is hidden from view” (Hall, 1966/1969, p. 189).

The concepts of space and information in their human dimensions, including space and culture, human problem solving, geometries of mind and the spatial organization of knowledge, will be discussed in the chapter that follows.

Chapter 4

INFORMATION AND SPACE IN HUMAN DIMENSION

A Three-Dimensional World: Space, Time and Culture

This chapter seeks to present some of the ways the human dimension is expressed in terms of our understanding of space and information processes. The intent of this work overall is to strengthen a human-centered concept of information processes. Open questions about spatial aspects of information sharing run throughout this work, and sharing must be considered to be a social, or human-centered process. The previous chapter on concepts of space concluded with reference to Hall's "hidden dimension," the cultural aspect of spatial relations. This chapter will provide an overview of some of the human-centered processes that are generally related to information, again with focus on the spatial aspects of those processes.

Topics that will be discussed here include cognitive maps and mental models, human strategies for understanding and action that often evoke analogies to geography and cartography. Discussion of these outward-looking concepts will be followed by examples of constructs for the geometries and maps of the mind, applying spatial concepts to help us understand our own thinking and related processes. In addition, such topics as sorting, physical manipulation as part of kinesthetic knowledge, and action orientation will be touched upon, to give a sense of the participatory approach to knowledge that needs to be part of a human-centered concept of information processes. In the sections below, an attempt will be made to keep acting human beings at the center of discussion. Space thus becomes a way of organizing or framing human actions in various ways. The human dimension always has personal as well as social aspects. Sometimes these may be expressed as a cultural dimension, or may be thought of as social-cognitive. The position taken here is that individual humans are embedded equally

in their social and physical worlds, in worlds of language and meaning as well as in a world of material constraints and the possibilities afforded by our physical bodies. Some of the complexities involved in adopting a human-centered approach are described in the sections that follow.

Overall, this chapter intends to support the view of Hall and others that consideration of culture is intrinsic to discussion of spatial and temporal dimensions. Hall has written, “What has been thought of as mind is actually internalized culture” (1976, p. 168). Hutchins, another author who stresses the importance of culture in cognition, aims to relax or dissolve boundaries that “have been erected, primarily for analytic convenience, in social space, in physical space, and in time” (1995, p. xiii).

In his introductory discussion of “mind at different levels,” Hampden-Turner calls culture “mind writ large.” “Culture consists of the sharing of mythic patterns, for meaning requires that we complete a picture whether we are certain of its final form or not. Culture is then mind writ large which shapes us unawares unless we develop the understanding to shape culture” (1981, p. 11).

Harley (1992) makes it clear that cartography is cultural expression. He contends that “the scientific rules of mapping are, in any case, influenced by a quite different set of rules, those governing the cultural production of the map.” He stresses that there is need to recognize rules “related to values, such as those of ethnicity, politics, religion or social class, and they are also embedded in the map-producing society at large. . . . In the map itself, social structures are often disguised beneath an abstract, instrumental space, or incarcerated in the co-ordinates of computer mapping” (p. 236).

Entrikin (1977) reviews two distinct approaches to spatial perspective that are represented in the work of empirical and phenomenological geographers. In distinguishing the existential space of the phenomenologists and the metric distances of the empirical geographers, “the question arises as to whether these two distinct spatial

perspectives can be reconciled within one philosophical framework or represent two divergent paths of geographic thought” (p. 209). This question persists in discussions of geographic theory today. Doreen Massey proposes that a thorough reconsideration by geographers of the concepts of space and time may help to build a bridge between the natural and social sciences, including their expressions in geography (Massey, 1999). The present work is intended to be a contribution toward this possible reconciliation.

Cognitive Space, Cognitive Maps, Mental Models, Geometries of Mind

Although the topics of cognitive spaces, maps and models generally are conceived to refer to the capacities of individual human beings, the preceding section should help us to remember that these also must be discussed in terms of their interpersonal human social context. This said, there is a sense in which cognition can be seen as being embodied in individual human actors, and most of the topics in this section are presented in a way that reflects this view. The sections below involve what might be thought of as spatialization of mental process, which is generally conceived in individual human terms.

Cognitive Space and Cognitive Maps

What is “cognitive space”? Couclelis and Gale (1986) state that cognitive space “includes the larger-scale space beyond the sensory horizon about which information must be mentally organized, stored, and recalled” (p. 2). For Newby, “Cognitive space is not just what is known (e.g. facts about the world) but also the dynamics by which knowledge is acted on, used, changed, etc. Processes in cognitive space are those required to store and retrieve knowledge, and also processes for integrating perceptions with experience, desires, the physical self, and so on” (Newby, 1998, p. 1).

This organization of information “beyond the sensory horizon” is thought to be performed through a mental strategy involving the construction of a cognitive map. The Dictionary of Psychology cites Tolman, whose observation of the behavior of rats in mazes initiated the cognitive map concept, in defining cognitive map: “A learned pattern of connected behavioral actions to achieve a particular end, be it a rat in a maze who wants to go to a food box, a child who wants to get dressed, or a student who wants to get a college degree” (Corsini, 1999, p. 181). Klatzky’s more restrictive definition applies only to physical space: “Cognitive maps are internal representations of spatial environments that permit the planning and execution of movement within them” (2000, p. 147).

The work of Downs and Stea is associated with increasing general awareness of cognitive mapping. They claim that cognitive maps are taken for granted as part of everyday activities. They assert that “human spatial behavior is dependent on the individual’s cognitive map of the spatial environment” (1973, p. 9). Cognitive mapping is the process of “acquisition, amalgamation, and storage” of “information from a complex, uncertain, changing, and unpredictable source via a series of imperfect sensory modalities” (p. 10). They ask, “How is information, derived from the absolute space of the environment in which we live, transformed into the relative spaces that determine our behavior?” (p. 12).

Geographers have an interest in cognitive maps in terms of hypotheses about how people manage their relations with their physical environment. The use of a “map” metaphor also makes this a comfortable concept for geographers. Downs and Stea state that “cognitive structures, or maps, serve as a frame of reference, a basis for interpretation, a source of behavioral predictions, and as a means of shorthand expression and communication.” The processes involved include our ability to “*rotate* environmental information in space, as in planning routes *to* and *from* a place.” We are

able to translate these structures through time. We are able to view the information included in cognitive maps from different perspectives. We can add or subtract elements at will. People demonstrate flexibility in their ability to change scales. Downs and Stea say that “Cognitive mapping is a process of both *analysis* and *synthesis*” (1977, p. 96). Their notion of cognitive mapping is grounded in a representation-of-reality model, and aims at understanding the basis for skills at spatial problem solving.

Tversky (1993, p. 14) explores the many nuances of conceiving of cognitive maps as “mental representations for environments.” These are known to differ from “true” maps (her quotations) but she claims that they are presumed to be like maps in being “coherent wholes that reflect spatial relations among elements.” They are “available to mental inspection” as maps are available to physical inspection. They are like images in being “internalized perceptions.” She calls her approach a “constructionist” view, by which people “acquire disparate pieces of knowledge about environments” of which “not all the relevant stored information will be retrieved when needed” (p. 15). Her “constructionist” approach should be distinguished from the constructivist approach described in Chapter 2.

To her description of cognitive maps, Tversky adds two other constructs: cognitive collages, and spatial mental models. In the case of cognitive collages, often operating “for environments not known in detail” the information will be systematically distorted, lacking “coherence of maps” but nevertheless good candidates as metaphors for environmental knowledge. The second operates where people have more detailed knowledge, and allow various operations to be performed, such as “perspective-taking, reorientation, and spatial inferences.” These may not “preserve metric information” but do well in preserving “coarse spatial relations” (Tversky, 1993, p. 15).

A recurring theme in the cognitive mapping literature is awareness of the discrepancy between the cognitive map and the environment that is being understood or

negotiated with the help of such a map. Tversky outlines many of the “systematic errors in memory” that are involved with these metaphoric operational structures (pp. 15-18). In discussion of the production of spatial descriptions (pp. 18-22) she concludes that though most languages provide people with the “technical systems to convey metric information about location, orientation, and distance, this terminology is not widely used in everyday speech,” (p. 22) but that people rather create descriptions using “categorical spatial relations” that are sufficient for everyday purposes.

Klatzky, in reviewing research into the “spatial accuracy of cognitive maps” (2000) notes that they “have nonspatial as well as spatial components and that they are influenced by processes of perception, learning, and meaningful interpretation. Research has been directed toward the underlying causes of systematic errors in cognitive mapping.” She claims that cognitive maps usually are formed by people through “perceiving and interacting with their environment. They use manipulation and locomotion as well as vision, thereby involving haptic modality (purposive touch) and proprioception (sensing via the muscles, tendons, joints, and vestibular system” (p. 147).

College in turn discusses the source of “biases” in geographic knowledge as being based in “cognitive filtering” (2002, pp. 7-9). These filters include the tendency to make irregular shapes regular, adjustments to fit reference frames, imposition of hierarchical ordering, and the addition of “biased personal knowledge.” He discusses the many ways in which people with only informal knowledge and without theoretical base can go wrong.

Hirtle and Heidorn stress the importance of structure when considering cognitive maps. They proceed from the assumption that there are “representations” of “actual three-dimensional space” that are the basis for spatial cognition, and put focus on the operations of that representation rather than on the “actual space” (Hirtle & Heidorn, 1993, pp. 170-171). They begin with an overview of the tradition of inquiry begun by

Lynch in *Image of the City* (1960), and describe the landmark, route and survey knowledge that are built up in the city image. Research into structured and unstructured representations of geographic spaces is reviewed, with the conclusion that where structures were not explicit, people would create hierarchical structures to assist in ordering space. These results are in line with perception studies of Gestalt psychologists, as are the perceptual adjustments noted by Golledge, above. They review research into the translation of cognitive maps into language when giving directions. Choosing reference objects and narrating spatial relationships among these objects is central to the process of giving directions. Choice and relations among reference objects may not reflect a “‘realistic’ picture of spatial relations” (p. 183), and for this reason spatial language reflects an “idealization” of actual relations. Finally, spatial language expressing cognitive maps depends on choice of points of view, described in terms of frames of reference as described in the previous chapter.

Although Hirtle and Heidorn’s view that cognitive maps can reflect actual spaces is called into question by the overall approach adopted in the present work, their conclusions about the importance of structure in spatial cognition seem correct. “We think that it is clear that space is not perceived, stored, or processed in a homogeneous manner. Structure and orientation within the space are used to organize the space, and in cases where no structure is available, one will be created. Therefore, in presenting information to people, it is important to present redundant, structured information. It is also critical to allow subjects to converse in a language of topology that allows for relations such as containment or adjacency, rather than strict Euclidean terms” (p. 186).

Most discussion about cognitive mapping seems to relate to human abilities as demonstrated in everyday activities, such as wayfinding and making judgments about spatial relations that are remembered or inferred. There are few hypotheses about what these maps actually are, in terms of human physiology and the neural processes by which

these abilities are exercised. O’Keefe (1996) discusses the presumed workings of the brain as it creates and uses cognitive maps. He states that these have three elements: places, directions and distances; and that the relations among them are maintained by vectors, in part due to physical positions, for instance the “head directions cells in the postsubiculum” an area adjacent to hippocampal region (p. 280). The forces whose vectors may influence the organism’s interpretation of direction may be present “as the local gradient of a universal signal such as gravity, geomagnetism, or olfactory currents, as the vector originating at a place or object and passing through another place or object . . . or as having a specified angle to a previously identified direction” (pp. 279-280). Most researchers would probably agree with Newby that “we must admit that our ability to describe and discuss cognitive space has outpaced our ability to provide a complete picture of how cognitive space actually works!” (1998, p. 8).

Kuipers discusses the distinction between the graphical map and the cognitive map. For many purposes (he gives examples from wayfinding) there is an indefiniteness, underdetermination of information available to the map user from the graphical map, and the cognitive map may be composed of logical frames in the user that are only loosely related to the graphical map. Map users are quite able to generalize from incomplete knowledge, both in their own cognitive maps and in available graphical maps. He concludes that graphical maps provide context for other information available to the user – a conclusion that may fit with the “heuristic” intent of the workspace developed here (Kuipers, 1978).

When space is defined from the viewpoint of geographers and geographic information systems, it often takes on a positivist coloration. Golledge, for instance, details the many “biases” in geographic knowledge due to “cognitive filtering” including the tendency to make irregular shapes regular, adjustments to fit reference frames, imposition of hierarchical ordering, and the addition of “biased personal knowledge”

(Golledge, 2002, p. 9). Identifying and exploring such biases is similar to the research gathered in Kahneman and colleagues in *Judgment Under Uncertainty* (1982). All of the “human conceptions of space” offered by Freundschuh and Egenhofer (1997) are tied to spatial relations in physical environments external to human observers, at various scales from “manipulable object space” and “map space” to “panoramic space.” All their spaces have some physical referent to serve as frame of reference for conceptualizing the space: “Transperceptual spaces . . . are learned via wayfinding experience over time” while “figural spaces are smaller than the body and are perceived from one vantage point.” They do not attempt, as Couclelis and Gale did in coordinating several orders of spatial relation toward extending these geographic spatial concepts to nonphysical, cognitive domains (1986). Harley provides a dissent from this overall positivist stance, which he considers to be a problem in contemporary cartographic practice: “One effect of accelerated technological change -- as manifest in digital cartography and geographical information systems -- has been to strengthen its positivist assumptions and it has bred a new arrogance in geography about its supposed value as a mode of access to reality” (1992, p. 231).

The entire cognitive mapping project among geographers seems to be oriented toward bringing the cognitive map into closer correspondence with the environment which it maps. Downs and Stea assert that cognitive maps “portray,” are the “likeness of,” are “simplified models” of the environment (1977, p. 6). They write of the “accuracy” of cognitive maps -- by which they mean the physical products of representation of the cognitive mapping process. “A *cognitive map is a product* – a person’s organized representation of some part of the spatial environment” (p. 99 ff.).

The theme of underdetermination, the generalization from incomplete knowledge as described by Kuipers above, is an important one. There seem to be two threads of approach to cognitive maps, one in terms of emphasis on problems related to their non-

correspondence with reality, and the other which focuses on people's ability to work with incomplete information and to make sense of it. These two tendencies, each with merit, also mark two approaches to information in general as well as characterizing two distinct approaches to understanding our relations with the world.

Mental Models

Mental models are similar to cognitive maps in several respects. Tversky defines a mental model as “a knowledge structure, like a schema, but more complex, as it not only represents information but also suggests how to process it” (2000, p. 191). She reports that the mental model construct appeared simultaneously in two forms, both sharing in the definition above but differing in the following way. On the one hand, she notes that Johnson-Laird (1983) used it as “a description of the mental structures used to solve verbal syllogisms, rather than the rules of logic, which are often violated” (p. 191). The essays in Gentner and Stevens (1983) used it “to characterize conceptual representations of knowledge of primarily physical systems, door bells, calculators, steam plants, electricity, mechanics, navigation. Mental models were seen as configurations of parts or processes causally influencing each other in specified ways. Like a schema, a mental model represents domain-specific knowledge; in contrast to a schema, a mental model incorporates processes that are temporal or causal in nature. Rather than being inspected, such a model is ‘run’ to draw inferences” (p. 191).

Tversky notes that the term model is used in two senses, “a model as a miniature of a real-world object or system and a model as a theory that generates predictions.” All of these distinctions lead to ambiguities surrounding our understanding of mental models, ambiguities which she claims are “not necessarily bad; it can be argued that many useful terms in psychology (and life) are ambiguous” (p. 191).

Since both cognitive maps and mental models are descriptions of processes that can be inferred from human speech and behavior, without their being available to direct observation, they can be conceived as explanatory constructs that make complex processes seem more manageable by means of abstractions available in metaphor.

Don Norman (1983) notes that “people’s views of the world, of themselves, of their own capabilities, and of the tasks that they are asked to perform, or topics they are asked to learn, depend heavily on the conceptualizations that they bring to the task” (p. 7) and that mental models serve these needs. “Mental models are what people really have in their heads and what guides their use of things” (p. 12). His overview of characteristics of mental models notes that they are incomplete, that they are unstable, that people don’t use them well, they don’t have “firm boundaries,” they may be unscientific, and they are parsimonious: “Often people do extra physical operations rather than the mental planning that would allow them to avoid those actions; they are willing to trade-off extra physical action for reduced mental complexity” (p. 8).

Norman, much of whose work has centered on exploring the interface between people and machines, says that system designers should work toward a “system image” that is “consistent, cohesive, and intelligible” (p. 13). Ideally, user interactions with the system will produce a mental model that is compatible with this system image. He presents distinctions between the conceptual model of the system (more or less the designer’s model), the system image, and the mental model. To have this repertoire of distinctions among models that are active in the design, learning and use of systems is meant to enrich the design process generally. In any case, the systems must work amidst the “messy, sloppy, incomplete, and indistinct structures that people actually have” (p. 14).

Murray notes that the Gestalt psychology was “ahead of its time in its emphasis on mental representations” as part of problem-solving processes, in that “it postulated

that subjects build up what we now call ‘mental models’ of the elements of a problem” (Murray, 1995, p. 165).

A classic article about mental models is Gentner and Gentner “Flowing Waters or Teeming Crowds: Mental Models of Electricity” (1983). Their goal was to understand how people construct and manage analogies related to complex systems. They describe the powerful role of “generative analogies,” which are mental models, in problem solving and theory building. In their narrative, common analogical constructs for understanding electricity involve water flows or moving crowds. To say that electricity flows like water, that an electric cord is a “narrow, controlled entity like a river” (p. 99) does not imply that people think that electricity is wet like water, but that there is a system of relationships that are thought to be shared across these domains. The moving crowd model has “objects racing through passageways” and voltages are interpreted as how hard this crowd pushes, a resistor as a gate controlling the crowd, and so forth. In their conclusions they cite many reports which show that people hold inaccurate and inconsistent models based on mental representations of physical phenomena that “contain profound errors” (p. 126). Their overall conclusion is that “Generative analogies can indeed serve as inferential frameworks” (p. 127).

In a more recent study, Levin, Stuve and Jacobson (1996) studied “mental models of networks.” Their study was done in 1996, when the emerging World Wide Web had not yet solidified into common models for the general public. They surveyed teachers and teachers in training for their images of e-mail, the Internet and the World Wide Web. Their work was aimed at better understanding of teachers’ concepts of technologies and their uses. Some of the “models” they elicited were web, highway, solar system, encyclopedia, fishnet, fungus with tentacles, nervous system, tree, interactive wave, and visual model of culture (novices), and community, foggy world, funnel, library, neural network, octopus, water molecule, ant trails, global village, and window on the world

(users with some experience) (pp. 4-5 of 14). Of particular interest to the work underway here is the vast range of images offered by these users, stretching the imagination but encouraging in the search for structures that afford many interpretations applied to interactions to a very diverse, distributed system.

Mental models have certainly played a part in the construction of the “heuristic workspace” that is one of the outcomes offered here, described in detail in Chapter 8 below. At this point, because the characteristics of the workspace are not fully defined nor described, its existence is as much in the form of a mental model as it is an actual space realized in a digital environment. Building physical models, which accompanied the creation of the digital space, affords a stability that is absent from the character of mental models as presented by Norman, who states “mental models are unstable” (1983, p. 8). Nevertheless, even the construction of physical models requires the coordination of a set of mental models. Likewise, without the physical and virtual models held directly before the eye or in the hand, the ability to mentally “hold” such a complex as three nested polyhedral nets would not be possible. Mental and physical models are each helpful in carrying out the required work of design. Having a physical model in hand has one advantage not available in the form of a mental model, which is the ability through demonstration to give others a sense of the model’s structure and functions.

Maps of Mind

This section presents “maps of the mind” which in a sense are complements to the mental models described above. Whereas cognitive maps and mental models are outward-looking, from the person toward the environment as a space to be navigated or a set of processes to be learned, maps of the mind are attempts to graphically illustrate mental and linguistic processes and other factors that make up the mind. Whereas cognitive maps aim to coordinate representations with a shared public and physical world

so as to better negotiate that world, “maps of the mind” are graphical interpretations based on measurement or on descriptive concepts of the workings of the mind of the cognizing subject.

Three of the examples presented here, Kelly, Osgood and Newby, derive their spaces from measurements of various factors that compose psychological, semantic and cognitive spaces. Hampden-Turner presents dozens of sketch drawings as “maps” that illustrate his review of theories of mind.

The psychologist George Kelly is known for his “personal construct theory” and for a metric called the role repertory grid, or Kelly Grid. This is a “matrix of concepts, individuals and constraints.” Leonard states that the “Kelly Grid is built on the premise that people construe their worlds by evaluating people, events, ideas, and objects (called elements) according to distinctions between their polar opposite characteristics. Each pole of each construct has meaning only when contrasted with its opposite” (Beer, 1994, p. 122). Shaw and Gaines (1992) claim that “Kelly was a keen geometer with experience in navigation and an interest in multi-dimensional geometry” (p. 2 of 15). Their Figure 11, “The RepGrid Screen showing a principal components analysis” is an array of vectors, similar to Osgood’s vector-based semantic spaces that are described below.

Shaw and Gaines continue, “It may seem strange to base cognitive science on geometry rather than logic until one remembers that the reasoning structure of the *Elements* (Euclid) was the basis for both Greek and modern logic, and that geometry and logic in a category-theoretic framework are equivalent” (p. 2 of 15). They cite Kelly (1955) for what they call his “fundamental postulate,” that a “person’s processes are psychologically channelized by the way in which he anticipates events” (p. 3 of 15). Personal constructs are “templets for construing events.” Kelly’s psychological space comes “into being through a process of construction by which we create a space in which to place elements as we come to construe them” (p. 3 of 15). This becomes a “coordinate

system for our experience” and the “topology of the space comes into existence as it is divided.”

Kelly calls his approach “constructive alternativism” (1969, p. 96) meaning that “reality is subject to many alternative constructions, some of which may prove to be more fruitful than others.” The personal construct is “essentially a dichotomous differentiating and integrating unit” (p. 104) that people deal with both categories and continua, and these qualities allow us to treat the personal construct as a mathematical function. “Each of our dichotomies has both a differentiating and an integrating function” (p. 105). For Kelly, choices are not made between doing something and doing nothing, but in choosing between two somethings. Since incidents (apparently, of anything) are “infinitely homogeneous,” differences must be interposed. This interposition defines the construct, which is an “intervening act” (p. 105).

The character of Kelly’s proposed geometry and arithmetic are given in two paragraphs at (1969, pp. 96, 105). There are no distances; each axis represents a single distinction, not a continuum; angles describe the relationships between contingencies or frequencies of incidents; these “change with the context of incidents to which the constructs are applied.” Kelly’s method of exploring personal constructs is to engage in a process of articulating similarities and differences beginning with the ways people put others into particular categories, establishing similarities and differences among them. By noting the constructs on a tabular matrix, the “construction matrix,” eventually “complete operational definitions” of a person’s constructs can be established (p. 109). The idea that each person constructs a multidimensional set of categories that can be expressed in a unique spatial construct is similar to ideas that motivated the design of the workspace offered below.

The methods of Charles Osgood, a pioneer of psycholinguistics, were very similar to those used by Kelly in deriving personal constructs. Osgood engaged in cross-cultural

studies of meaning, toward developing an “Atlas of Affective Meanings,” and devised a new “semantic space vehicle” (1971, p. 39). He explicitly postulated a spatial model for semantic space: “Let me ask you now to do the impossible -- to imagine a hypothetical semantic space of some unknown number of dimensions, but certainly larger than the three to which our human estate gives immediate entree.” He offers colors as analogy, and uses as a base “a locus of complete *meaninglessness* analogous to the neutral grey of the color space.” A concept at that position would “have no distinguishing semantic characteristics. The meaning (*M*) of any concept located elsewhere in the space could be represented by a vector extending from the origin.” He then goes on to provide analogies to color’s saturation, brightness and hue, and relates these to the direction and length of the vectors in semantic space. Direction, however, requires “the existence of some reference coordinates or dimensions.” As a way to conceive “psychological opposites in language” he provides another color analogy, of complementary colors, cancelling each other as represented in equal and opposite directions from center (Osgood, 1971, pp. 7-8)

The heart of his method is a coordinate system of multiple bi-polar relationships, and Osgood likens his method to the game of Twenty Questions (p. 9). His scales represent a “distance from meaninglessness” measure (p. 42) exploring 620 concepts organized into 12 “super-categories” (p. 46). He carried out an extensive cross-cultural program of research, while acknowledging shortcomings “due mainly to the intricacies of culture and the questionable validities of the intuitions of native informants, even very highly motivated ones like our colleagues” (p. 57). He clearly states that at the time of his work neither he or anyone else had a “rationale for sampling the conceptual domains of human cultures” (p. 40). The cross-cultural work of Levinson and colleagues, described above in the discussion of frames of reference in Chapter 3, could legitimately be situated in the research tradition initiated by Osgood.

Newby, whose work is within the information sciences with particular interest in the processes of search and retrieval, uses a version of multidimensional scaling based on the “Galileo theory” of Woelfel and Fink to delineate cognitive space (Newby, 1998). “Galileo theory posits laws of cognitive processes similar to the laws of physics. In a Galileo cognitive space, survey items (referred to as ‘concepts’) have not only location, but also cognitive equivalents to mass and velocity. ‘Mass’ is associated with how much knowledge and certainty exists about a concept. ‘Velocity’ is simply the tendency of a concept to move (or sometimes oscillate) relative to other concepts over time. The Galileo cognitive space is not an empty space with occasional concepts in it, such as graphical depictions of the solar system. Rather, it is akin to an Einsteinian space-time, in which forces exist between items in the space, such that there is no truly empty space, only areas of more greatly concentrated ‘mass’ and their associated forces” (p. 5). This introduction of the concepts of “forces” will be expanded in Chapter 5.

Though Hampden-Turner’s “maps of the mind” are not based on quantitative measurements, they have the advantage of providing evocative illustrations of the wide range of established theories of mind (1981) . He recognizes that his is an unorthodox approach to the visual display of relationships expressed by our ideas about the human psyche, but the graphics he presents are effective icons for the narrative provided in the text Many of the names that appear elsewhere in the present study appear among the “maps” he presents: Varela, Bateson, Osgood, Fuller, Korzybski, Piaget, and the “force fields of Kurt Lewin”.

His maps are as diverse as the theories they illustrate, showing objects in space, fields of force, complex networks, multi-headed and multi-species trees, machines and paradoxical figures. Common to most is some portrayal of the human head. There also is an overall sense of the forces at work in the mind. The images are evocative invitations to the reader to reflect and interpret the details given in the narrative text. The variety and

depth of the “maps” give the reader a sense of the chaotic nature of the mind, no doubt an important factor in our inability to derive a single or consistent view of its workings. Hampden-Turner is explicit about his goals and alternative intellectual commitments. “This entire book is a plea for the revision of social science, religion and philosophy to stress connectedness, coherence, relationship, organicism and wholeness, as against the fragmenting, reductive and compartmentalizing forces of the prevailing orthodoxies” (p. 8).

Given that people construct and use cognitive maps and mental models, what are the materials from which these are composed? Like all cognitive processes, these seem to be composed from at least three major streams that are involved in encoding, and decoding, our perceptual experiences. Two of these are words and images, the factors involved in Paivio’s “dual coding” hypothesis for memory (Paivio, 1979, pp. 177- 243). He presents three “different theoretical levels of meaning – representational, referential, and associative” (p. 177) giving special attention to the place of imagery in symbolic processes. Paivio also points toward a third factor that can be generally identified as kinesthetic. “In agreement with theorists such as Osgood (1953), Werner and Kaplan (1963), and others, I assume that the aroused meaning process evoked by a word or other symbol is an organismic reaction with affective, or motor (including verbal), or imaginal components, or all of these at once” (Paivio, 1991, pp. 109- 110).

Other authors also embrace the kinesthetic factor. Levelt presents three “multiple representation systems” of the mind: “spatial representation system, propositional representational system, kinaesthetic and other representational systems” (1996, p. 78). We also recall Klatzky’s haptic and proprioceptive factors in the construction of cognitive maps (2000, p. 147). All of these authors point toward understanding cognitive processes in terms of multidimensional participation in our experience and in our ability to mentally manage it.

In the present work, the kinesthetic factor is expressed within the heuristic workspace model presented below in terms of real spatiality, the ability to move and rearrange symbolic tokens, and inclusion of “forces” among the defining elements of the structure. Manipulability, the involvement of the hands as well as the eyes and ears, seems to be an essential component of learning and memory. This comes up here in several contexts, such as the importance of sorting as a basic information activity (described below); the movement and rearrangement of symbolic tokens within the workspace, importance for retrieval of having put something physically in a place.

Sorting, Categorization, Manipulation

This section introduces sorting as an important and fundamental information process. People are constantly engaged in sorting through fitting objects and concepts into categories and groups, often without much reflection about the basis on which this sorting goes forward. The concept of sorting is easily associated with physical activities related to moving objects from one place to another, into and out of groupings that change depending on situation and time. Most sorting seems to go forward on informal, ad hoc basis, and is pragmatically related to immediate goals.

The formal approach to sorting is classification, closely linked to giving stable names to things and concepts. The dynamic and situational character of most sorting works against the stability needed in formal systems of classification. There is a movement away from an approach to categories based on a classical theory, toward a view of categories based on exemplars and prototypes, an approach identified with Eleanor Rosch. The sections that follow will expand on these themes.

Everyday Sorting and Theories of Categorization

Sorting is an everyday activity, one of the basic activities associated with information processes, as are losing and finding things and the questioning / answering process. Sorting involves making order, essential to the “sense-making” said by Dervin to be the core of information. Making order and the origin of forms begins with drawing distinctions. “We take as given the idea of distinction and the idea of indication, and that we cannot make an indication without drawing a distinction. We take, therefore, the form of distinction for the form” (Spencer-Brown, 1969, p. 1).

Sorting closely relates space and information, since the most familiar kind of sorting involves moving things, rearranging them physically, creating sets of objects in physical space. There seems to be little doubt that something similar happens when sorting involves nontangibles, such as happens with the rearrangement of ideas toward creating order in thought. Ideas, or concepts, are often spoken of as if they were physical objects, the “folk solids” that are said to be the materials of cognitive processes (Clark, 1993, p. 4).

Sorting “creates space” in a practical sense. If a random array of objects is scattered in a physical setting, such as tools on a workbench or working papers in a study, sorting them actually creates space, working room in which new activities can take place that were not available amidst the confusion and random clutter – itself the result of tendencies toward disorder, entropy. This disorder began with yesterday’s order and resulted from the accomplishment of yesterday’s tasks. Everyday sorting is “negentropic” action, a mark of the ongoing creativity that is one way of distinguishing living from nonliving processes.

While it is usually conceived as a mechanical process, more like housekeeping than as one of the creative arts, sorting can also be a learning strategy. The first kind of learning that sorting allows is an understanding of the relationships among the things

sorted, and awareness of the particular criteria that are applied when any sorting occurs. Sorting rules can be inferred from the arrangement of the sort while it is ongoing and when complete. Sorting also allows recombination in unique situated orderings that can be seen as the results of a creative process. In these ways, mere sorting can be the source of new insights about the ordering of relations in our world. The space that is created through sorting has the potential for making room for new choices that might otherwise not be available; the increase of choices being one of the main goals of informational activities generally.

Categorization is part of sorting. Sorting can't be done unless there is a prior sense of how distinctions are to be drawn in the process. Drawing distinctions is a rule-based activity, though in the case of most everyday sorting the rules can be very general and informal. The categories that are involved often are loosely defined or even totally tacit, inexplicit, or part of background assumptions that operate but are seldom recognized, often part of the "cognitive unconscious" hypothesized by Lakoff and Johnson (1999). Which might be fine, if being unconscious of the criteria for any particular sort does not stand in the way of the purposes for which the sort is undertaken. Drawing distinctions on habitual or unconscious basis, or accepting socially-determined distinctions uncritically, may result in decreased availability of choices, excluded choices of which the person doing the sorting will probably be unaware.

Our approach to sorting is generally judged on pragmatic bases. The appropriateness of any category, concept or rule according to which formal or informal sorting takes place can be judged only in its consequences, both for the person engaged in sorting, and in the consequences of the sort in its implications for others.

Names and the naming of things is also intrinsic to sorting, though sorting can happen without names for the categories or objects being made explicit. Names that are assigned to objects, or to sorting rules, may have serious unintended consequences.

Examples are given by the linguist Whorf in his classic article on the “relation of habitual thought and behavior to language” (1941/1956). His examples were taken from his years working as a fire insurance inspector, where he found exhaust fans that were thought to be “blowers” and thus blowing the fire across the factory; a flammable substance called “rock wool” that was thought to be noncombustible due to being “rock” and then suddenly exploding; and other equally compelling examples.

Considering classification processes as a spectrum, sorting occupies the informal pole, while classification occupies a more formal region. Much of the effort in constructing information storage, search and retrieval systems has gone toward managing categories, toward goals of consistent arrangement within the system and toward issues of coordination between categorical assumptions of system users and the arrangements of the system. Certainly part of the mental model of users of information retrieval systems has to include something about how categories are managed by the system, but the congruence between user and system-based categorical structures cannot be as close as most machines require.

Svenonius discusses the rules for formation of the vocabulary of “classification languages” (2000, p. 56), stating that these rules can be simple or complex, derived from the works being classified or from controlled vocabularies. She finds that “little progress has been made in automatically classing terms into semantic categories” in part because “the information needed to do it is not sufficiently formalized or consolidated” (p. 145). Some new tools are becoming available, “that consolidate and normalize lexical information. . . . These tools can be found in the form of lexical databases that combine dictionary and thesaural information, databases mapping natural to normalized languages, metathesauri, semantic networks, term banks, and various sorts of knowledge representations. Such tools hold promise for advancing the automation of semantic classification. Nevertheless, semantic classification will always be difficult. . . . Where a

human intelligence cannot unequivocally class a term, a machine intelligence can hardly succeed” (p. 146).

Part of the problem in constructing consistent vocabularies for classification languages, and the difficulties nonspecialists have in using them, is that they are based within the traditional, or classical, approach to categories. Controlled vocabularies such as the *Library of Congress Subject Headings* and the thesauri used in indexing specific subject domains usually involves a classical approach to categorization. The hold of this theory has diminished recently, largely due to work within a tradition initiated by Eleanor Rosch.

The classical theory of categories, and the importance of Rosch’s recognition of the importance of prototypes for categorization, is detailed by Lakoff (1987). “From the time of Aristotle to the later work of Wittgenstein, categories were thought [to] be well understood and unproblematic. They were assumed to be abstract containers, with things either inside or outside the category. Things were assumed to be in the same category if and only if they had certain properties in common. And the properties they had in common were taken as defining the category.” He continues that this was “arrived at on the basis of a priori speculation . . . not even thought of as a theory . . . but as an unquestionable, definitional truth” (p. 6).

Based on Rosch’s work, Lakoff outlines the questions have been raised regarding consequences of the classical theory. First, “if categories are defined only by properties that all members share, then no members should be better examples of the category than any other members;” also, if properties are inherent in the members, then “categories should be independent of the peculiarities of any beings doing the categorizing; that is, they should not involve such matters as human neurophysiology, human body movement, and specific human capacities to perceive, to form mental images, to learn and remember, to organize the things learned, and to communicate efficiently” (p. 7).

Lakoff's colleague Mark Johnson ties the classical theory of categories to an "Objectivist" theory of understanding, of which he is critical. "A theory of categorization is basic to any theory of cognitive structure, for it explores the way we organize our experience into *kinds*. Objectivist semantics has tended to factor the set-theoretical view of a category as specifying necessary and sufficient conditions for membership in a given kind" (Johnson, 1987, p. 191). Now Rosch's alternative is available, supporting the view of "categories as consisting of networks with prototypical members clustered in the center of the category with less prototypical members at various distances from the central members. A category thus forms a complex radial structure, and we would need an account of the nature of these structures, to the extent that they vary in kind" (p. 192).

Paivio, whose particular interest is in the role of imagery in memory, finds that Rosch's exemplars often are remembered and used in the form of images. "Some recent evidence strongly suggests that we use specific pictureable exemplars as the prototypical representations of general categories. Rosch showed experimentally that not all category instances are equally good members of the category. . . . Rosch has demonstrated that people who are required to deal mentally with general concepts in an experimental task tend to think in terms of the prototypical best examples rather than vague abstractions or even verbal labels. . . . Moreover, Rosch was able to show that people somehow evaluate the category membership of other exemplars by comparing them with these prototypical examples. That is, good prototypes serve as reference points or standards against which other examples are compared. Finally, some of these good prototypes have considerable generality or universality [cross-culturally]" (Paivio, 1991, p. 263).

A good summary of Rosch's prototype theory of categorization is found in Mark and Frank, who align themselves with Lakoff and Johnson's "experiential realism" (1996). They describe how experiential realism approaches the problems with a classical set theory approach to categories, in which "there are necessary and sufficient observable

properties of any entity, from which its membership or non-membership in some set can be deduced without ambiguity” (p. 4).

Understanding the nature of the everyday activity of sorting, how we make sense, order and space in our lives through the use of categorical judgments such as are advanced by Rosch, should be useful in bringing the categorical structures of human participants into accord with the definitional frameworks built into information systems, or interactive learning environments. Svenonius, in the passage cited above, indicates some of the ongoing work toward alternative approaches. These ideally would maximize the use of such features of categorization as individual differences, graded membership in classes (prototypes), and peoples’ “basic level categories,” which are “determined by the way people interact with parts of their environment, and thus will depend upon their gestalt perception, image formation, motor programs, functions and purposes” (Johnson, 1987, p. 192).

Generally, when sorting is done by machines, all the characteristics of the sort are well defined, as in the set-theoretic approach to categories. Machine-based processes often result in structures of meaning that are well defined, but that ultimately enforce the establishment of universal meanings to which users are compelled to conform. New approaches, based on a more open understanding of the process of categorization as practiced, may lead toward a more contextual, relational, situational, and distributed notion of the organization of meaning than is now the case. In part, the approach of federated autonomous workspaces suggested in Chapter 8 is proposed as one design strategy in this direction.

Action Orientation, Lived Space, Kinesthetic Knowledge

The fundamental unity of the physical/geographic and the social/cognitive worlds is experienced in human lived space. The human dimensions of space and information

are expressed in this section through examples of what are meant by action orientation, for instance situating responsibility for information in terms of human choices, and by what might be called kinesthetic knowledge, also discussed by various authors in terms of embodiment and manipulation, or the knowledge of the hands.

As suggested in the previous section, sorting is a fundamental informational activity, and through our physical or “embodied” actions directly relates information with space. As Bowker and Star observe, “To classify is human. Not all classifications take formal shape or are standardized in commercial and bureaucratic products. We all spend large parts of our days doing classification work, and we make up and use a range of ad hoc classifications to do so. . . . We have certain knowledge of these intimate spaces, classifications that appear to live partly in our hands -- definitely not just in the head or in any formal algorithm” (Bowker & Star, 1999, pp. 2-3).

That our knowledge is embodied, that our concepts originate in our physical as well as our linguistic and intellectual activities, and that our memories and other cognitive processes are intimately tied to our bodies are themes that recur throughout the present work. Our classifications, and many other aspects of our cognitive processes, do “appear to live partly in our hands.” Understanding this is one of the ways that we can begin to make the person-centered approach to information real. This section will discuss several aspects of this.

The “motor theory of perception” of Alain Berthoz is one point of beginning toward seeing these concepts together as an integrated whole. “A major theme of this book [*The Brain’s Sense of Movement*] is that perception is more than just the interpretation of sensory messages. Perception is constrained by action; it is an internal simulation of action. It is judgment and decision making, and it is anticipation of the consequences of action” (Berthoz, 1997/2000, p. 9). The book suggests that the sense of movement may be considered a “sixth sense” (p. 25 ff.). There are senses of position and

velocity; sensation and control of these are in several physical organs, such as the “neuromuscular spindles” that detect muscle stretch (p. 27) and the semicircular canals, that he asserts gives the body a “basic Euclidean frame of reference” (p. 33) that we also find in the Euclidean basis of Weber’s cognitive geometry (2002).

Berthoz reviews Poincaré’s geometric, representative and retinal spaces. Geometric space is “continuous, infinite, three-dimensional, homogeneous (all its points are identical), isotropic (all the straight lines that pass through the same point are identical). In contrast, representative space (which is primarily visual space) is two-dimensional (retinal space); it becomes three-dimensional owing to convergence and accommodation; it is not homogeneous, because the part of the retina that is most sensitive to shape, the fovea, is nonhomogeneous with the periphery. It is thus not isotropic.” Berthoz suggests that a basic intuition of Poincaré is affirmed by “modern psychophysics;” that is, “we do not *represent* to ourselves external bodies in geometrical space, but we *reason* about these bodies as if they were situated in geometrical space. . . . Poincaré introduces a fundamental notion that is essential to my own theory: ‘To localize an object simply means to represent to oneself the movements that would be necessary to reach it. I will explain myself. It is not a question of representing the movements themselves in space, but solely of representing to oneself the muscular sensations which accompany these movements and which do not presuppose the preexistence of the notion of space’” (Berthoz, 1997/2000, p. 37).

In these ways, Berthoz helps us to understand the importance of the actions of our bodies in relationship to our perceptions and our knowledge. The focus of this section, lived space and the actions we perform in it, is linked to a phenomenological approach to geography, space and design.

Kimberly Dovey seeks to integrate lived space, the actual requirements of individual and institutional clients for architectural projects, with the geometric space

that is one of the tools for architectural and environmental design. She states that there is a distinction between “lived and geometric modes of space,” with focus on lived space characterizing “the phenomenological approach to environmental studies” (Dovey, 1993, p. 247). Citing Norberg-Schulz (1971) in an approach to categorizing lived space in a similar fashion as Freundshuh and Egenhofer (1997), discussed above in the Chapter 3, she distinguishes various scales of lived space ranging from the “level of small objects” that is “centered around acts such as grasping and manipulating” through the “level of furniture,” the “scale of building” and “larger geographic scales” (Dovey, 1993, p. 249). She introduces the concept of “zones of actual and potential reach,” citing Schutz and Luckman (1973) and recalling the work of phenomenological geographers Buttner and Seamon (1980).

Dovey reflects that “Plato declared in the *Timaeus* that geometry should be the science of space. Subsequent developments through Euclid have built geometric space into a powerful model for understanding the world. This model is so powerful that a geometric representation of the world is widely perceived as the one true arrangement, with people’s various everyday experiences being more or less accurate in relation to it” (p. 248). For phenomenologists, “the lived-space of the lifeworld is the primary spatial mode from which geometric space is abstracted” (p. 249). She refers to Merleau-Ponty who “asserts the priority of lived-space . . . firmly anchored in the nature and structure of the human body and the potentialities for action” (p. 249). The potentials of space within an action orientation are shown in her quotation from his *Phenomenology of Perception*, “Space is not the setting (real or logical) in which things are arranged, but the means whereby the positing of things become possible. . . . [I]nstead of imagining [space] as a sort of ether in which all things float . . . we must think of it as the universal power enabling them to be connected” (p. 249).

Distinct from lived space, Dovey claims that geometric space “is purged of social and cultural meaning; it is reduced to the coordinates of a map or the lines of a technical drawing. It achieves accuracy and predictability at the expense of experiential depth” (p. 250). Nevertheless, the geometric space that is available to us is of great value. “The irony of geometric space is it is the elimination of human values that makes it useful;” while lived space “is the opportunity-laden setting for action in everyday life,” (p. 250) geometric space “is a means to improved lived-space, a shared language that contributes to a successful design process. This cycle from experience through geometric representation and back to a transformed experience I call the *cycle of lived-space*” (p. 251).

Dovey outlines many of the problems encountered in architectural design related to an inability to express lived space through simple geometric portraits as in working drawings. She advocates for revised design process, allowing “a critical analysis of the design process to ensure that the primacy of experience is not lost to the complexities of scale of the development” and asserts that “the lived-experience of place both initiates and concludes the process of environmental change” (p. 267). Her perspective has a bearing on the results that are suggested in the present work, in that she asserts the positive value of geometric approaches (a large factor in the design of the workspace, below), and in that she puts the “lived-experience of place” at the beginning and end of the design process, as is intended here in putting the cognizing human subject at the beginning and end of all information processes.

Edwin Hutchins, whose “cognition in the wild” seeks to establish the human actor as a whole person, not only a brain, and social relationships as the locus of cognition, not just the external “physical symbol-system architecture.” Reflecting on traditional cognitive science, he states that the “physical symbol-system architecture is not a model of individual cognition. It is a model of the operation of a sociocultural system from

which the human actor has been removed” (Hutchins, 1995, p. 363). “When the symbols were put inside (computer or brain), there was no need for eyes, ears, or hands. Those are for manipulating objects, and the symbols have ceased to be material and have become entirely abstract and ideational” (p. 365).

Hutchins describes the place of nautical charts aboard a naval vessels as important shared, visible workspaces around which a social cognitive process can occur (p. 271) and describes the origins of mathematics in physical manipulation of tools that had physical as well as symbolic aspects (p. 361). He points in two directions simultaneously, outward from the head to inclusion of the body and the society, and inward from abstract symbol management systems toward the embodied person. His perspective forms part of the basis for the conceptual design of the results that are presented here.

This standpoint may give us some insight as to why paper remains so important for our own situated understandings for their interpersonal communication. Malcolm Gladwell, reviewing Sellen and Harper’s book *The Myth of the Paperless Office*, describes the importance of small, physical slips of paper called “flight strips” to the work of air traffic controllers. He recounts that “as a controller juggles all those planes overhead, he scribbles notes on little pieces of paper, moving them around on his desk as he does. Air-traffic control depends on computers and radar. It also depends, heavily, on paper and ink” (Gladwell, 2002, p. 92). The use of these basic data sheets has defied migration to computer. Sellen and Harper find that “paper has a unique set of ‘affordances’ -- that is, qualities that permit specific kinds of uses. Paper is tangible: we can pick up a document, flip through it . . . quickly get a sense of it. . . . Paper is spatially flexible, meaning that we can spread it out and arrange it in the way that suits us best. And it is tailorable: we can easily annotate it, and scribble on it as we read, without altering the original text.”

Gladwell proceeds to discussion of the organization of desks, and the “prevalence of piles over systematic filing” (p. 93). This may be a “sign of complexity: those who deal with many unresolved ideas simultaneously cannot sort and file the papers on their desks, because they haven’t yet sorted and filed the ideas in their head.” The flight strips are particularly important for the air-traffic controller because they help in creating “situation awareness” through the construction of a “three-dimensional ‘picture’ of all the planes in his sector” (p. 96). In other words, the manipulation of actual physical objects, such as slips of paper and papers piled not filed, is an important strategy for constructing a working model of knowledge required for everyday activities.

Similar results were reported by Malone in studies of how people organize their desks (1983). One of his respondents stated, “Well, see the hardest problem for me organizationally is deciding what the categories are and what category something is in” (p. 107). This points toward an important factor in all cognitive processes, that not all factors that are in fact accounted for have clear categorical definitions. Malone suggests that office information systems should allow “two of the functions of conventional desks: easy storage of loosely classified information and convenient use of visible reminders” (p. 111).

David M. Levy (2001) advocates for an awareness of the continuing importance of physical documents in a world that is increasingly motivated toward their digitization. He contrasts paper with digital documents in terms of their “bounded” versus “divided” existences. “A paper document is complete in itself, with the communicative marks inscribed directly on the writing surface -- one or more sheets of paper. The ensemble is a self-contained, bounded object. It weighs a certain amount, feels a certain way, and is always located somewhere: on your desk, in a briefcase, on your refrigerator, or folded and stuffed in a pocket. Its digital counterpart, however, has a divided existence; it lives a double life. . . . Digital materials are made up of both the *digital representation* and the

perceptible forms produced from it” (p. 138). In his view, physical documents are integral to the “world-making, or culture-making, business” and “help us exert power and control, maintain relationships, acquire and preserve knowledge” (p. 159).

The observations about the continued usefulness of paper are not meant to detract from the advantages of managing documentation and communication in digital environments. Rather, they serve to emphasize the importance of such activities as construction of information through actions such as sorting, the importance of kinesthetic and postural memory, and the role of manipulation or the knowledge of the hand. This should point us toward inclusion of related facilities in our computerized, or digital exosomatic extensions.

The integrative design process advocated by Dovey earlier in this section is similar to the approach of Bamberger and Schön (1991) that they characterize as “reflective conversation with materials.” Their core concern was, “Can we, from a careful and rigorous study of the process of making things, gain insights that will apply to learning and invention in domains more usually considered ‘cognitive’ -- making solutions to problems in math and science, solving puzzles within constrained task situations, inventing new theories? In short, how can making a real object inform making things in domains thought to be quite different from the arts and crafts? . . . At some point . . . we set ourselves the task of trying to capture moments in which individuals actually came to see in new ways” (pp. 186-187).

In one of their research settings, people without previous musical training were observed in their making of tunes. They characterized the result as a “reflective ‘conversation’ between makers and their materials in the course of shaping meaning and coherence” (p. 190). “Improvising, uses elided into one another, new relations, new meanings emerged, and these, in turn, reshaped the makers’ knowledge-in-action with respect to this task. In this way the tune-builders’ commonplaces of possible things to do

with the materials, together with their still unarticulated criteria for making musical sense, gradually became *things to think with* in their work of making a tune that they liked” (p. 208). There was mutual change of process, between finding and making, a “transaction between finding and making -- finding in the materials what we know already and simultaneously making something new of them . . .” (p. 208). This “finding in the materials” recalls Gibson’s recognition of the “affordances” directly perceived by organisms in the objects and conditions of the physical environment (Gibson, 1979/1986, p. 127 ff.) and Storm’s “eolithic” rather than linear approach to the use of materials in the conduct of design (Storm, 1953).

Interviewed about his approach, Schön observed, “As you work a problem, you are continually in the process of developing a path into it, forming new appreciations and understandings as you make new moves. The designer evaluates a move by asking a variety of questions, such as ‘Are the consequences desirable’ ‘Does the current state of the design conform to implications set up by earlier moves?’ ‘What new problems or potential have been created?’” (Schön & Bennett, 1996, p. 175).

Their recognition of the importance of interactions between people and their working materials recalls the perspective of Csikszentmihalyi (1993) who shows acutely awareness of the interpenetration of people with the objects in their lives. The relationship between people and their things has both positive and negative aspects. On the one hand, “Most people require an external order to keep randomness from invading their mind” and objects thus help “stabilize and order the mind” (p. 22). On the other hand, artifacts are both symbiotic and parasitic on their “human host.” “When things are necessary to prove dominance and superiority, human costs start to escalate very quickly. It is striking to note in comparison how inexpensive things that stand for kinship and relatedness tend to be. Tokens of remembrance, respect, and love typically have trivial intrinsic value, and the labor invested in them is usually voluntary” (p. 28). His remedy:

“The addiction to objects is of course best cured by learning to discipline consciousness. If one develops control over the processes of the mind, the need to keep thoughts and feelings in shape by leaning on things decreases. This is the main advantage of a genuinely rich symbolic culture: It gives people poetry, songs, crafts, prayers, and rituals that keep psychic entropy at bay. . . . We very much need to learn more about how this inner control can be achieved. Then objects can again be used primarily as instruments rather than as projections of our selves, which, like the servants created by the sorcerer’s apprentice, threaten to drown their masters with relentless zeal” (p. 28).

The theme of the development of knowledge structures through physical interaction with the environment runs throughout the present work. We recall Klatzky’s claim that cognitive maps are formed within people “by perceiving and interacting with their environment. They use manipulation and locomotion as well as vision, thereby involving haptic modality (purposive touch) and proprioception (sensing via the muscles, tendons, joints, and vestibular system)” (Klatzky, 2000, p. 147). Likewise, Gollege and Hubert (1982, p. 108) observe: “Distance itself is conceived by a process of intellectual synthesis that involves an equilibration both of motor experiences and of visual effects.”

The examples given above are meant to illustrate the involvement of the total person, especially in terms of physical involvement in learning and information processes. These suggest that information involves participation. In addition to the physical or kinesthetic aspects of participation, active participation is involved in communication and in the interpretive aspects of language understanding. Communication through language always involves active listening, which is a creative process, while the conduit metaphor for communication tends to emphasize the role of listener as passive receiver rather than as active creator as participant in information processes.

In addition to active, creative listening, speakers must take responsibility for appropriate framing of what they say, so that listeners will be more likely be successful in their task. All expressions in language are underdetermined. Robyn Carston (2002), who bases her work on Sperber and Wilson's "relevance-theoretic framework," suggests a "linguistic indeterminacy thesis" which identifies this underdeterminacy in at least 3 forms: 1) "Linguistic meaning underdetermines what is meant." 2) "What is said underdetermines what is meant." 3) "Linguistic meaning underdetermines what is said" (p. 19). Similar to this linguistic underdeterminacy is what might be considered a "spatial underdeterminacy" as suggested by Downs and Stea: "Obviously there are innumerable ways of characterizing the whatness and whereness of a location. No single, limited set of attributes can provide adequate knowledge for solving all spatial problems. The nature of the problem itself determines which attributes are relevant or irrelevant, important or unimportant. The problem also determines what is considered to be an object" (Downs & Stea, 1977, pp. 54-55).

The concept of implicature often frames discussions of the underterminacy of expressions. This concept derives from the work of philosopher H.P. Grice, and is "frequently used in linguistics as part of the study of conversational structure. Conversational implicatures refer to the implications which can be deduced from the form of an utterance, on the basis of certain co-operative principles which govern the efficiency and normal acceptability of conversations . . ." (Crystal, 1997, p. 191). The linguist Stephen Levinson (2000), whose work was described earlier in relation to linguistic frames of spatial reference, has also elaborated a "theory of generalized conversational implicature." The three linguistic frames of reference identified elsewhere by Levinson (1996), by which spatial concepts can be distinguished, can now also be seen in context of the notion of "implicature" or necessary ambiguity and uncertainty that accompanies all speech acts, which are counted "among the devices . . . that languages

use to encode distinctions” (Harnish, 1992, p. 66, referring to work of Sadock and Zwicky (1985) on universal fundamental speech acts). Setting up of such distinctions seems to be an essential prerequisite for communication in general.

Implicature is discussed in other places in the present work, particularly in exploration of the place of questions in information systems. The point here is not to summarize theories about conversational practices that serve to reduce the necessary underdeterminacy of expressions, but to simply emphasize that this condition exists. Resolution of the intrinsic ambiguities in all expressions must involve some measure of active participation in the communication and information process, either as the speaker who frames utterances or as the active and creative listener. Appropriate framing of what is said and participation through active listening are preliminary to the successful negotiation of meaning. All of these conditions should be accounted for and included in information systems design.

Strategies for resolving uncertainties and ambiguities in communication reminds us of Bateson’s concept of “metacommunication” (1972/2000). His definition of information is “the difference that makes a difference,” and these differences have to do with the choices available to participants in the informational processes underway. Metacommunication is that part of communication aimed at helping us to make well-informed choices about the meanings that are involved in any conversational setting. Bateson presents this concept in a number of sources, including his writings on schizophrenia. He suggests that this pathology is related in part to an inability to decode messages, especially certain “more abstract labels which we are most of us able to use conventionally but are most of us unable to identify in the sense that we don’t know what told us what sort of a message it was. It is as if we somehow make a correct guess. We are actually quite unconscious of receiving these messages which tell us what sorts of message we receive” (pp. 194-195). These messages about messages are what he calls

metacommunication, an often implicit signalling that serves to orient participants toward the relevant purposes and contexts of the conversation, which also are at the core of problems associated with underdeterminacy in language.

Finally the action orientation to information suggested here is intrinsic to Michael Polanyi's concept of personal knowledge. "I regard knowing as an active comprehension of the things known, an action that requires skill. Skilful knowing and doing is performed by subordinating a set of particulars, as clues or tools, to the shaping of a skilful achievement, whether practical or theoretical. We may then be said to become 'subsidiarily aware' of these particulars within our 'focal awareness' of the coherent entity that we achieve" (M. Polanyi, 1962, p. viii).

Spatial Organization of Knowledge

The concluding section of this chapter will review some traditional approaches that have been taken toward organizing knowledge spatially. These include the "method of loci," a mnemonic strategy used in classical rhetoric; the occurrence of "commonplaces" as used in learned discourse; and the more recent concepts such as "circle of knowledge" as expressed through such innovations as the "encyclopedia" and the physical arrangement of books in the 19th century British Museum Library. Some examples of spatial structures related to knowledge organization in computing environments will supplement these traditional and historic approaches.

The most well known of the traditional mnemonic practices as taught in classical rhetoric is known by several names, including the "method of loci" or the construction of a "theater of memory." The standard history for this mnemonic approach is Frances Yates' *The Art of Memory* (1966). Further discussion and many graphic illustrations of classical and medieval "mnemotechnic devices" can also be found in Murdoch (1984, p. 72 ff.). Sandberg (1997) gives a cognitive basis for these approaches. "The first form of

cognitive amplification strategies developed was cognitive tools, internal software that helps us organize thoughts and memories. . . . The method was based on the simple observation that we are good at remembering things inside a context, so given a stable, easy to remember context information could be linked to it and then easily retrieved” (p. 7 of 14).

Allan Paivio uses references to these traditional strategies of memory to illustrate his own “dual coding” theory of memory, in which linguistic elements and visual imagery are equal partners in our ability to learn and recall. Paivio’s outline of traditional memory systems (1979, pp. 153-175) guides the overview presented here. Knowledge of these traditional systems comes to us from classical texts such as Cicero’s description of Simonides in Cicero’s *De oratore*. Cicero summarizes the method: “persons desiring to train this faculty (of memory) must select places and form mental images of the things they wish to remember and store those images in the places, so that the order of the places will preserve the order of the things, and the images of the things will denote the things themselves, and we shall employ the places and images respectively as a wax writing-tablet and the letters written on it” (quoted by Paivio at p. 154).

According to this method, a large selection of places is required, which are then remembered in a certain order, and which also then can be used multiple times for different purposes. The person who carried the method to the greatest extent was Giordano Bruno. His aim was “to encompass and unify the world of appearance and the supercelestial world of ideas using the memory tradition and astrological notions. The intermediaries between the two levels were to be magical star-images organized according to the associative structure of astrology. The grand aim was no less than that of grouping, coordinating, and unifying all the multiplicity of earthly phenomena within memory through the organization of significant images that derive magical power from

the stars. Through the celestial images, the confused plurality of things becomes unity” (Paivio, 1979, p. 164).

Bruno’s method adopted features of the system of Ramon Lull, involving “concentric circles that could be revolved to produce different combinations of concepts” (p. 165). Bruno’s was a round celestial system coordinated with a square architectural system, composed of 24 memory rooms, divided into 9 memory places, further divided into fields and cubicles, where “everything in the physical world -- plants, stones, animals -- and all the arts, sciences and human activities were to be represented in these rooms by images. The round celestial system juxtaposed with the square plan (perhaps as a round building encompassing a square one) contained the celestial figures and images which were to animate, organize and unify the detailed places and images contained in the memory room” (p. 165). This was “a dynamic system in which the static elements can be combined and recombined by rotating the Lullian concentric wheels to yield different combinations of ‘subjects and predicates’” (p. 166).

Paivio states that these traditional systems embody the “implicit assumption, among others, that concrete objects and events, or their verbal surrogates, are easier to remember than more abstract stimuli” (Paivio, 1979, p. 177). In describing the origins of his dual coding theory of memory, Paivio relates a “conceptual peg experience” that was itself about “conceptual pegs” (Paivio, 1991, pp. 1-18). As a beginning graduate student in psychology at McGill in the early 1950s, Paivio was exposed to a mnemonist whose method involved linked pairs of evocative nouns that rhymed with the cardinal numbers. This opened for him the tradition of memory devices in classical rhetoric, often involving the association of concepts with specific places, particularly architectural.

The elaborate celestial circle / architectural square approach adopted by Bruno, as described by Paivio, recalls for us the form of traditional cosmological charts, another genre of spatial knowledge organization.

The theater of memory and method of loci seem closely related to strategies of spatial cognition such as the mental tours or “gaze tours” described by Tversky (Tversky, 1996, p. 469). Downs and Stea (1977) describe the “mental walks” of the memory prodigy “S.” They quote from Luria’s *Mind of a Mnemonist* (1968, pp. 31-33) that S. “found some way of distributing these images in a mental row or sequence . . . [he would] take a mental walk . . . ‘distributing’ his images at houses, gates, and store windows.” They claim that this sort of activity takes cognitive mapping “another step further: to associate *nonspatial* information with a well-known cognitive map” (p. 97).

Also similar to the method of loci are the “commonplaces” in language that tie places and concepts together. Walter Ong, writing about the cultural periods in which oral traditions prevailed, claimed of commonplaces that “one could even argue that they were in many ways *the* center of the culture” (Ong, 1967, p. 31). He viewed commonplaces “as oral residue,” the “information storage and conceptualization” of oral culture (p. 79). In many ways we might think of commonplaces as “headings” but traditionally they were thought of in terms of place, or *topos* (p. 80). This *topos* in Greek became our topic, and topical commonplaces existed for such concepts as “causes, effects, contraries, comparable things, related things, and so on” (p. 81). As with the method of loci, commonplaces were used in rhetoric as “a set of headings enabling one to analyze the subject or an accumulated store of readied material, or both, previously composed or excerpted, to which one resorted for ‘matter’ for thinking and discoursing” (p. 83).

The spatial aspect of this concept survives in the form of “topic maps” that will be called upon in later sections as a strategy for establishing connections across digital workspaces.

Before moving from these concepts that prevailed in classical and medieval times, an alternative approach stressing the importance of what might be thought of as

“no-place” for the world of thought. This is the *topos noetos*, or place of thought, as recalled for us by Hannah Arendt. She asks, “Where is the *topos noetos*, the region of the mind in which the philosopher dwells? . . . Framed in spatial terms, the question received a negative answer. Though known to us only in inseparable union with a body that is at home in the world of appearances by virtue of having arrived one day and knowing that one day it will depart, the invisible thinking ego is, strictly speaking, Nowhere” (Arendt, 1978b, p. 11). “The thinking ego, moving among universals, among invisible essences, is, strictly speaking, nowhere; it is homeless in an emphatic sense - which may explain the early rise of a cosmopolitan spirit among the philosophers” (Arendt, 1978a, p. 199). “Philosophers love this ‘nowhere’ as though it were a country (*philochorein*) and they desire to let all other activities go. . . . The reason for this blessed independence is that philosophy (the cognition *kata logon*) is not concerned with particulars, with things given to the senses, but with universals (*kath’ holou*), things that cannot be localized. . . . In other words, it may well be that we were posing a wrong, inappropriate question when we asked for the location of the thinking ego. Looked at from the perspective of the everyday world of appearances, the everywhere of the thinking ego – summoning into its presence whatever it pleases from any distance in time or space, which thought traverses with a velocity greater than light’s – is a *nowhere*” (p. 200).

Approaching perspectives more familiar to our contemporaries, we should remember that the encyclopedia is literally the “circle of knowledge” (Wells, 1968) and that the circular form for the organization of knowledge was adopted in the design for the reading room of the British Museum Library (Edwards, 1859).

The spatial organization of knowledge is also reflected in the comprehensive subject classifications that have been established for libraries up to the present time. The philosopher Patrick Wilson (1985) details the problematic relationship between classification systems and the need to provide locations for books in libraries. He cites

Cutter's dictum that a library's "dictionary catalog" should "show what the library has . . . on a given subject" while adding that it may not be "obvious what 'being on a given subject' meant" (p. 319). Wilson claims that "place has no definite sense" in terms of library classification: "No single feature, and no cluster of features, set off the writings at one position from those at all other positions; the rules of assignment prescribe nothing definite, and no confident predictions can be made about what will be found in the writings at a given place."

Wilson stops just short of stating that books are where they are in a library because that's where the librarians put them. Yet we may reflect that when managing physical objects such as books, they must be put somewhere, and some sense of order is preferred to no order at all. The constraints that hold for physical objects in physical locations are relaxed in digital environments.

A thorough overview of current attempts to structure knowledge spatially in digital environments, along the lines that have been attempted since classical times, is given by Chen (2003, pp. 67-99) especially in the chapter "Mapping the Mind" which includes the "memory palaces" tradition and suggests the potential usefulness of traditional visual displays such as Asian mandala. The approaches to spatial organization of knowledge in digital environments discussed there include cognitive maps, geographic maps, visualizations of multidimensional scaling, networks, trees, concept mapping, and clustering. The chapter concludes with a history of research into the small worlds phenomenon, and its geometric representations.

The construction of information spaces, virtual spaces and cyberspaces, all of which should be considered as being in the tradition of spatial organization of knowledge, has been treated in various ways by some of the authors who are sources for ideas expressed in the present work. Couclelis (1998) explores the possibilities and difficulties involved in "the construction of information spaces." She describes data

visualization, multidimensional spaces “representing quantifiable variables,” and phase spaces from the physical sciences designed “to represent the state of arbitrarily complex systems in n-dimensional variable space, to which conventional methods of analytic geometry apply” (p. 211). She notes that an outstanding problem with such abstract spaces is that they “are practically impossible for humans to conceptualize, visualize, or explore in their full richness” (p. 211). Concepts that are familiar in Euclidean space such as proximity and distance, angles, orientations and shapes “are much harder to interpret” in these abstract spaces. She quotes Benedikt’s “Cyberspace: Some Proposals” (1991, p. 123) and concurs with his thinking that spaces constructed for virtual worlds “must resemble the space-time of human experience: ‘Cyberspace has a geography, a physics, a nature, and a rule of human law’ not as an empirical fact, but by pragmatic necessity” (p. 212).

Benedikt is a “designer and theorist in architecture” (1991, p. 120) who has focused on design aspects of cyberspace. Benedikt suggests that constraints “may be designed into it toward optimal use” (p. 123). In this space, physical objects are replaced by objects “in form, character and action, made up of data, of pure information” (pp.122-123). The design of appropriate constraints, modeled on the constraints of physical space, place and time, is one of Benedikt’s preoccupations. He posits that everyday conceptions cannot be arbitrarily overturned in cyberspace, and he advances a set of principles against which cyberspace design may be judged. Of special interest is his “principle of transit” which enforces discontinuities into cyberspace design, requiring stepwise traversal of this space.

Benking and Judge (1994, at p. 5 of 5) suggest that adoption of the approach of “memory palaces” might serve the “need for such visual metaphors to enable individuals to handle information overload and retain some control over the information they endeavour to possess. Spatial metaphors can be seen as vital to retaining possession of

information and avoiding ‘memory leakage’ or the effective ‘dismemberment’ of one’s information space.”

The workspace that is presented in the Chapter 8 fits in many ways within the traditions of spatial organization of knowledge outlined here. It has characteristics of the method of loci, and emphasizes clustering of concepts around conceptual landmarks that are similar to commonplaces. It is a generic space that can be made available for a variety of purposes, organizing a variety of geometries in a way similar to the variety of architectural forms that needed to be available to classical rhetoricians. It affords a diverse variety of patterns, frames of reference and nested coordinates, available in a synoptic view, all to be defined by the person organizing the space.

This chapter has provided a broad overview of information and space as they interpenetrate all dimensions of human thought and action. Rather than being seen as universal constants, space and information are recognized here as being qualities that depend on human agency for their existence and meaning. This approach reflects Hall’s suggestion that a third, “hidden” dimension of culture should always be considered when the more familiar dimensions of space and time are in mind. This chapter has attempted to make many facets of this human dimension more visible, toward providing an adequate and plausible ground for the adoption of a human-centered approach to information.

Chapter 5

FORCES AND STRUCTURES

This chapter introduces a theme that may serve as a bridge from the mainly theoretical considerations presented earlier, to the attempt to engage these mainly abstract considerations in the service of a specific design task. One of the consequences of the discussion of the dominant metaphors for communication and information is the search for an approach that would minimize the object character of the information concept. An intimation of this is presented here in an exploration of how structures and stability can be thought to result from interacting forces as they do from the arrangement and connections of physical materials.

The resonance metaphor for information, introduced in Chapter 2 and elaborated in Chapter 7, suggests that interactive information processes can be conceived in some measure as propagating waves, an alternative to the alternatives that emphasize information as object. The object of the design task here is a multi-dimensional space that is composed of a set of nested three-dimensional figures, that together afford a diverse set of information processes and relationships to be visualized. This chapter provides background in terms of the relationship between forces and structure as is embedded the design concept.

Along with these two main points of focus, some discussion will be presented related to the concepts of patterns, stability, and social structure, all of which are related to forces and structures, and also which have a direct relationship to the overall design process that is underway here. The discussion here, as in the rest of this work, seeks to deemphasize the role of objects in our thinking about information. To speak of structures in terms of forces leads also to the notion of stability without objects, stable structures that result from stable patterns of interacting forces rather than from fixing relations

among tangible objects, such as is the case with most building architecture. Although the organization of knowledge may have a spatial structure (as in examples given in the section on spatial organization of knowledge in Chapter 4), that structure does not have to be the result of the piling up and connecting of physical objects.

Forces

The concept of force is used in describing physical, cognitive and social processes, in much the same way that space is a characteristic dimension of many different worlds or frames of reference. The idea of force is not a simple one, though its meaning seems to be easily understood in everyday terms. Because forces often are vague, local, changing, observed differently by various observers (in sum, not often measurable in universally agreed terms) they are often excluded from the design of formal systems such as information systems. Forces are not as safe and predictable to work with as are objects and the relations among objects. Yet excluding forces, or not making a place where forces can at least be acknowledged, may be a shortcoming that limits the potentials of the systems we design.

The concept of forces has been invoked by several of the authors whose works are relied upon here. For Alexander, forces are integral to the emergence of patterns, which form the vocabulary from which his pattern languages are composed. Mark Johnson suggests “compulsive force” as a fundamental image schema that pervades our structures of meaning. Buckminster Fuller settled on the interaction between discontinuous compression and continuous tension as a solution for some of the structural problems he was trying to resolve. The result was the “tensegrity.” This approach is consistent with his attempt to characterize the world generally in terms of energies and events, rather than in terms of objects. Gestalt psychologist Wolfgang Köhler discussed stability in our perceptions in terms of the balancing of forces. For John Searle and others involved in

the theory of speech acts, “illocutionary forces” are involved in the performative aspects of language, and one of these forces is expressed in the form of questions, or interrogatives.

Several perspectives on forces will be outlined briefly below as they have a bearing on the present work. The existence of interacting forces is implied by the resonance metaphor, and how structures may result from interacting forces is described in the section below.

It is intended that the digital workspace structure presented makes room for the representation of many diverse interacting forces. If we are inclined to say with Couclelis that “Information is the relation that connects a sign with an intentionality” (1998, p. 211) then this intentionality, a kind of force, should be accounted for, or accommodated, in the design concept for an information system. In similar fashion, the “commitments” that Winograd and Flores assert are a defining factor in organizations (Winograd & Flores, 1986, p. 158) should be accommodated, as well as the many factors of interest and attention that are part of information processes.

We might begin to think of forces in terms of relationships among objects, that the structure of these relationships is due to the intersections of forces. Forces somehow drive the relationships among things located in situated contexts. The relationship between forces and structures is given by Alexander as the model for the complex interactions from which patterns emerge.

Alexander was a pioneer in the creation of map overlay techniques for public infrastructure planning (see Alexander, 1966; Steinitz, Parker, & Jordan, 1976). The direction he eventually took with this work was very different from that which resulted in the development of geographic information systems. He generalized the method of map overlays, not in the direction of quantification of the features on each layer and calculation of the relations among layers, but toward the recognition of forces and

patterns that were implied in the ensemble of conditions expressed in them. His early work, leading to his eventual method of “pattern languages,” involved complex environments such as highway and rural village planning. For an early design problem, siting a highway in Massachusetts, twenty-six criteria or “forces” were charted for the terrain, then combined to search for a solution. He analyzes numerical, analog and relational methods of analysis, and then states the problem in the form of this question: “*Given a set of forces, WITH NO RESTRICTION ON THEIR VARIETY, how can we generate a form which is stable with respect to all of them?*” (Alexander, 1966, p. 107).

Alexander defines patterns in the following way: “Patterns have the following generic form: Context --> System of forces --> Configuration” (Alexander, 1979, p. 253). “We see, in summary, that every pattern we define must be formulated in the form of a rule which establishes a relationship between a context, a system of forces which arises in that context, and a configuration which allows these forces to resolve themselves in that context.” He specifically defines a problem as a “field of forces” (p. 251). He uses the expression, “from a set of forces to a form,” to describe the process. Discovery of what the forces are that are at work in a particular context, toward the creation of appropriate solutions that express these, is the essence of Alexander’s design method. The usefulness of pattern languages as a way of approaching the complexity of intercommunity communication and documentation was suggested in several ways during the discussions of the New Directions project (see Harrap, Journeay, Talway, & Brodaric, 2001; Hunting, 2002).

Alexander cites the earlier work of D’Arcy Thompson, *On Growth and Form*, where Thompson calls form a “diagram of forces”: “The form then, of any portion of matter, whether it be living or dead, and the changes of form which are apparent in its movements and in its growth, may in all cases alike be described as due to the action of force. In short, the form of an object is a ‘diagram of forces,’ in this sense, at least, that

from it we can judge of or deduce the forces that are acting or have acted upon it . . .” (Thompson, 1961, p. 11). Guy Davenport (1987, p. ix) gives the origin of the phrase “every force evolves a form” as Mother Ann Lee (1736-1784) “founder of the Shakers. In its practical sense, this axiom was the rule by which Shaker architects and designers found perfect forms. . . . As an ideal, that form is the best response to the forces calling it into being has been the genius of good design in our time, as witness Gropius, Le Corbusier, Rietveldt, Mondriaan, Sheeler, Fuller.”

Mark Johnson, the philosopher who has partnered with George Lakoff in exploring the role of metaphoric processes in our language and structures of thought, takes the image schema of “compulsive force” as one of the major examples used throughout his book *The Body in the Mind* (1987). An image schema is “not a concrete rich image or mental picture; rather, it is a more abstract pattern that can be manifested in rich images, perceptions and events” (p. 2). It is a proposition to the extent a “proposition exists as a continuous, analog pattern of experience or understanding, with sufficient internal structure to permit inferences.” The *compulsion* schema has “internal structure consisting of a force vector (with a certain magnitude and direction), an entity acted upon by the force, and a potential trajectory the entity will traverse” (pp. 3-4). We have seen that this schema can be implicated in the motivating forces expressed in the pathways metaphor.

Johnson says that these experiential schema have “internal structures” that exhibit “*gestalt* characteristics, that is, their nature as coherent, meaningful, unified wholes within our experience and cognition” (p. 41). He then outlines “preconceptual *gestalts*” in our “forceful encounters with other objects and persons. Because force is *everywhere*, we tend to take it for granted and to overlook the nature of its operation. We easily forget that our bodies are clusters of forces and that *every* even of which we are a part consists, minimally, of forces in interaction.” Only when forces are “extraordinarily strong, or

when they are not balanced off by other forces,” as in high winds or when walking uphill, do we notice the forces that are always parts of our lives (p. 42).

Forces always involve interaction, movement in some direction, a single path of motion, “the vector quality of forceful movement,” have origins or sources, “*degrees of power or intensity*” (p. 43) and there is always some “*structure or sequence of causality involved*” (p. 44). This is the “*gestalt structure of force.*” This “gestalt structure of force” seems similar to the processes that Alexander identified as the source of his patterns.

R. Buckminster Fuller, another thinker whose ideas were helpful in conceiving of the design of the heuristic workspace, consistently worked at eliminating material objects from his worldview, opting instead for an event-based cosmology. “Since physics has found no solids or impervious continuums or surfaces, and has found only finitely separate energy quanta, we are compelled operationally to redefine the spheric experience as an aggregate of events approximately equidistant in a high-frequency aggregate in almost all directions from one only approximate event (Fuller, 1975b, p. 710). Kenner reports that of Fuller’s sense of things, his “most important model for reality is *energy radiating from a center, and being restrained.* (The center may be just a point of reference . . .)” (Kenner, 1973, p. 93). Edmondson recounts Fuller’s quest for a “comprehensive coordinating system;” what kinds of structure would come about within it? For Fuller, she says, it had to do with requirements of “minimum energy . . . necessarily a result of the balance between specific forces and inherent spatial properties” (Edmondson, 1987, p. 10).

Two structures expressed these interactive forces best for Fuller, the “Dymaxion” (his trademarked word for his applications of a particular Archimedean solid, the cuboctahedron) and the “tensegrity” that was jointly invented by Fuller and the sculptor Kenneth Snelson. Fuller also called the cuboctahedron a “vector equilibrium” due to the equivalence of an “omnidirectional arrangement of forces” unique to it, unit vectors

originating at the center and ending at each vertex are also of the same length as edges linking vertices (Edmondson, 1987, p. 91). Edmondson sketches Fuller's critique of spheres in the following terms: "The notion of a continuous surface equidistant from a central point is scientifically unacceptable, that is, inconsistent with physical reality; on some level of resolution all 'spheres' consist of discrete quanta -- untold numbers of energy events interconnected by an even greater number of vector-relationships, or forces" (p. 238). A cuboctahedron is the most central of the three nested polygons in the workspace described in Chapter 8. See Figure 8 for an illustration of this figure.

The second of Fuller's structures that has relevance here, the tensegrity, exhibits the "tensional integrity" of relations that involve discontinuous compression elements and continuous tension elements. The fascinating behavior of tensegrities can be shown in physical models that show these interacting forces in a way that description and illustration cannot. The biologist Donald Ingber makes a case for identifying tensegrity structures as being integral to many of the life forms on our planet, including the internal structure of the cell and our body's skeleton (Ingber, 1998). A comprehensive overview of the tensegrity concept, with suggestions on building tensegrities, has been given by Pugh (1976).

Kenner (1973) says that a tensegrity is a system that looks precarious but is very resilient, and that it expresses how "the interplay between force and restraint settles into a spherical pattern" (p. 93). He notes Fuller's observation that tensegrities behave like balloons (which physical tensegrity models do), and that a "balloon is a successful restraint of an explosion" (p. 93). In many ways tensegrities demonstrate the same forces that make up the surface tension that holds a droplet of water together (see description and illustration at Random House Encyclopedia, 1990, Fig. 4, p. 1504). An image of a tensegrity is the second of the three nested polyhedra incorporated into the workspace described below; see illustration at Figure 7. It is the most likely candidate to represent a

“question space,” with questions arrayed along the tension members and current knowledge represented by compression struts.

Forces also are used by linguists to explain certain characteristics of “speech acts.” Speech act theorists consider utterances in terms of the “illocutionary forces” that are expressed in the conversation: “The ‘illocutionary force’ or act the speaker intends to perform in speaking can be expressed explicitly” or more usually through such strategies as inverted word order, intonation, or leaving parts of sentences out (Dewdney & Michell, 1997, p. 54). Huddleston (1994, p. 3845) says that sentence types “grammaticalize” these illocutionary forces. There are many ways in which sentences can be classified into “different kinds of speech acts -- of acts with different illocutionary force.”

Mark Johnson explains Searle’s concept of speech acts through the formula $F(p)$ where “‘p’ represents the *propositional content* of the utterance, while ‘F’ is the *illocutionary force* with which that content is presented.” For example, Johnson says “The utterance ‘Did John run away?’ can be analyzed as a propositional content (*John ran away*) presented with the force of a *question*.” In this way, Searle “has constructed a taxonomy of speech act types that lays out the kinds of forces there are and the kinds of conditions that must obtain if the speech act is to be successfully performed” (Johnson, 1987, p. 58). Thus, “in most speech acts there will be a content presented *under* or *by means of* a given force.” Johnson further states that a “relevant gestalt . . . will be that for *COMPULSION*” and then explicitly links this schema to Reddy’s conduit metaphor for communication, involved with “sending this filled container along a conduit or through space to the hearer” (pp. 58-59). Questions, of particular interest in the present work, are an example of “illocutionary force.”

Several of these authors refer to *gestalt* qualities that accompany the expression of forces. The Gestalt psychologist Köhler asks about the role of regularity, symmetry,

and simplicity in “the distribution of the material and the forces within the system? There seems to be a very simple answer. When such regular distributions are being established, more and more components of the acting forces are likely to balance each other, which means that under these circumstances the equilibrium or a steady state is quickly or gradually approached. But in a closed system the action of forces does operate in the direction of equilibrium or a steady state. It is therefore not surprising that during this operation the distributions within the system become more regular, symmetrical and simple” (Köhler, 1969, pp. 58-59).

These interacting, balancing forces that together characterize a whole, which is taken by the Gestalt psychologists as being the unit of perception, again point toward the close relationship between forces and structures. Some notes on structures are given in the section that follows.

Structures

What are “structures”? The idea of structure come up throughout this work, particularly in terms of the internal relationships that may be expressed in frames of reference. Structure literally means piling up, as of stones; it means the organization of parts with some relationship to a larger whole; and it means “form,” and through form it directly relates to the word “information.”

Structures may result from the interactions of natural forces, or may result from conscious design decisions. That structures do not need to be thought of in terms of the piling up of stones should be clear from the previous section, yet this notion of building with physical materials remains central to our ideas of structure. To the extent that people build structures, it is legitimate to ask who may be responsible for any structure, including the forms that are involved with any informational instance or event. A theme

in the overall presentation here is that opportunities should be afforded to individuals and communities to reassert control over structuring processes.

Weber quotes Arnheim's *Art and Visual Perception* (1954) on the contributions of the Gestalt psychologists to the role of structure in perception: "The experimental findings demand a complete turnabout in the theory of perception. It seemed no longer possible to think of vision as proceeding from the particulars to the general. On the contrary, it became evident that overall structural features are the primary data of perception . . ." (Weber, 2002, p. 20). Köhler (1969) states that "structure" refers to "a functional aspect of processes, to the distribution of such processes, a distribution which they assume (and may also maintain) as a consequence of the dynamic interrelations or interactions among their parts" (p. 92) and that only by being "structured functional wholes" can the "dynamic structure of the physiological processes in the brain" be "directly related to organized visual perception" (p. 93). We again see that structure is involved with perception and processes, as well as the more material forms that the word brings to mind.

Structure also has to do with stability. Often stability, a dependable "place to put things" that is relatively known and persistent over time, is needed more than "more information." This sort of structure is what Wurman (1989) illustrates with his "hatrack" concept of information organization. Structures allow us at least the representation of stability. The creation of the tensegrity by Fuller and Snelson demonstrated a structure that is self-stabilizing, that embodies dynamic forces and change, in fact is made up of these, but still affords resilient stability.

If one of the essential aspects of information processes relates to action in several forms (in making choices and the acts of discriminating, of drawing distinctions, sorting, and categorizing) then a fundamental informational action can be related to the construction, evolution or emergence of the structures, which are defined by these

actions. Something must be held stable as environment for this activity – call it context, or background, or ground in the figure-ground Gestalts that characterize our perceptions in all frames of reference and their dimensions. Structures help to maintain stability among the relationships in the frames.

Stability is never permanent. Moments of stability may be attained (such as when a question is answered, a problem is solved, etc.) but immediately these are introduced into a new spatial/temporal/material/cultural context (or situation, chronotope) that itself begins the process of instability, creative disequilibrium again.

Fleischaker (1984, p. 46) observes that stability for Maturana and Varela is an outcome of what they call autopoietic processes, involving identity, circularity and integrity (stability as result of interactions). He asserts that Varela and Maturana's view renders "impossible the position of the system observer external to the human mind, an element required within the traditional model" (p. 48). The "traditional duality of external object and reflected internal representation is denied. . . . Indeed, the concept of reflection is itself denied since all observations originate within the world of human cognition: One cannot properly speak of any 'mirror' since there is no 'mirroring.'" Again, paradoxical conditions occur, in fact are the result of human biological and cognitive processes, from which stabilities result.

All symbols are two-sided in nature, with a formal / structural / material side and an ideational / semantic / side. Bleier (1987, p. 1) calls these two facets the "ontological" and the "metaphorical." This is evident in the actual structures we live in and negotiate daily, such as our homes, workplaces and public buildings. Architecture has self-evidence as material structure, but also is a meaningful arrangement of materials in space. Wurman (1989, p. 6) suggests that an "airport is an example of how structure and meaning might work together. In an airport, the space itself should indicate paths and alternative paths through a series of functions that eventually get you on to a plane.

Designed effectively, this is the *architecture of information*.” This two-sidedness can perhaps be thought of as structure and semantics, or form and meaning. Always these aspects are needed in co-relation.

There is another kind of structure that is relevant to the present work, the social structure, which is one half of the social-cognitive whole and into which the metaphor and workspace need to be introduced and tested through use. The sociological theories of structuralism were introduced in the 19th century via Marx and Durkheim, who according to Heydebrand “conceived of social structure in holistic and nonreductionist terms, i.e., not as an aggregation of individual actors, but as social facts *sui generis*, explainable only by other social facts” (2001, 15230). He asserts that for Marx the “central social fact” was political economy; for Durkheim it was “social ties and norms.” In anthropology structuralism is identified with the work of Claude Levi-Strauss, and it shows affinity with Gestalt, understanding through pattern recognition, “games theory, and the mathematical theory of communications and cybernetics.” Barnes (2001, 15222) fits this structuralism to “Gestalt psychology with its emphasis on the perception of patterns Indeed, games theory, the mathematical theory of communication and cybernetics are obvious and acknowledged sources of some of his more unquestionably structuralist ideas.” These are ways in which social structuralism and the information sciences as disciplines have interpenetrated.

Collins calls Durkheim’s the “core tradition of sociology” (1994, p. 181). In this structure, “the surface is symbol and ritual, the depths are nonrational and subconscious. This intellectual tradition focuses on themes of emotional forces, morality, the sacred, the religious - and declares that these are the essence of everything social.” A chart relating trends in this tradition (p. 182) names Mauss, Levi-Strauss’s structuralism, “Goffman’s interaction rituals,” Mary Douglas, and Bourdieu’s “cultural capital theory” (p. 186). Forces again are at work, as in “Durkheim’s Law of Social Gravity.” “Durkheim’s key

explanatory factor is social morphology, the structural relationships among people” (p. 187). “There is nothing mysterious about this: by structure, Durkheim means the actual, physical pattern of who is in the presence of whom, for how long, and with how much space between them. Differences in this social density have profound effects on people’s ideas and moral sentiments, hence, on their capacity for rational thought, bargaining, suicide, and anything else one cares to examine. . . . The basic determining factors are the structural relationships among individuals, not the individuals themselves. Historical change happens mechanically, independent of individual wills, by a kind of ‘law of gravitation of the social world.’” In this tradition, the phenomenon of “ritual exchange networks” is identified with Marcel Mauss. These relations include ceremonial exchanges and gift exchanges including the “everyday politeness that Goffman analyzed” (p. 229). In these ways societies structure relationships, including the “information sharing” that is one of the motivating questions in this work.

How we conceive of the global web of social relations as a structure is in transformation. Heydebrand (2001, 15231) notes that social network analysis is taken to be a “contemporary sociological structuralism. . . . Networks differ from organizations and institutions in that they are informal, private, self-organizing, noncontractual, unregulated, unaccountable, nontransparent, and typically of limited focus, size, and duration.” Representations he includes are Simmel’s “web of group affiliations” and Blau’s “theory of structural sociology.”

The network idea of social organization is also to be found in Castells’ “network society” (Castells, 1996), in the “small worlds hypothesis” (Buchanan, 2002) and in the importance given to lateral information sharing networks in today’s global scene (Meyer, 1997).

In this chapter, discussion of the idea of “forces” has been explored as an alternative to focus on “objects,” part of the overall shift implied by the work that is

reported here. This shift is useful in terms of processes related to information, especially when alternatives to the information-as-object metaphor are sought. This approach is to look at objects, entities, structures in a way that goes beyond the fact of their existence, and to consider such aspects as origins, goals, problems to be solved by means of particular structures, that may express interrelated forces rather than configurations of matter.

To attempt to describe the world in terms of the forces that operate rather than the objects that constitute it is a frame shift. Fuller tried to define and inhabit a world of events and energies rather than matter, and claimed that his view was in accord with the results of contemporary physics. There is difficulty in bringing our everyday thoughts and actions into conformity with alternative worlds. This task reminds of Chrisman's observations on "the debate between absolute and relative space." Beginning with Kant's *a priori* space, and following Newton, "space was taken by most as an immutable, timeless, immaterial void that had a permanent truth." In this century, modern physics "has overthrown the concept of absolute space" (Chrisman, 1978, p. 2). The new ideas, implying a "highly relative approach to frames of reference," have not migrated to general acceptance in terms of our available language of spatial relations.

In a similar vein, Buchanan (2002, p. 155) notes that "Physicists in particular have entered into a new stage of their science and have come to realize that physics is not only about physics anymore, about liquids, gases, electromagnetic fields, and physical stuff in all its forms. At a deeper level, physics is really about organization -- it is an exploration of the laws of pure form."

The notion of "pure form" finally reminds us that the core term in information is the word "form." Information is one of many words that derive from the Latin *forma*, which itself is related to the Greek *morphe*. Some other words that derive from *forma* include form, formal, formulate, conform, reform, etc. These all have mainly to do with

the concept of shape, both in the active sense “to give shape” as in making a figure from clay, and also referring to the shape of a thing (Shipley, 1984, pp. 66, 252). A person-centered view of information might thus see it as an activity that is related to making order, or giving form, to structures of thought within.

This section provides a transition between the resonance metaphor and description of the heuristic workspace. Whereas the resonance metaphor has moved from object-orientation toward focus on relationships and processes, the workspace needed a structure. Beginning to show how forces and structures are thought to be related is the key point of this section. The account of forces and structures presented here began with Christopher Alexander’s “from a set of forces to a form.” His description of patterns as the resolution of forces, grounded in contexts, became the vocabulary for an approach to architectural design. Overall, structures can be seen as the expression of forces, and even though they may not even be made up of any physical components (Fuller would say that energy and events compose the world entirely) we still can have stable structures accounted for in this scheme. Part Two will explain how forces and structures are coordinated in terms of the resonance model and heuristic workspace, based in the goal of creating a suitable space for the construction of a question-centered learning environment.

Part Two

RESULTS, CONCLUSIONS AND FUTURE WORK

Chapter 6

QUESTION-CENTERED LEARNING ENVIRONMENTS

Introduction

The second part of this thesis presents the results and outcomes that are based on the investigations and perspectives that were presented in Part One. The most tangible of these is the creation of a structured multidimensional digital workspace, called a “heuristic workspace,” that is described in Chapter 8 below. This workspace accomplishes the spatialization of the core concepts that are intrinsic to an alternative metaphor for information processes, termed the “resonance metaphor for information.” This metaphor was introduced earlier, in the concluding sections of Chapter 2, and is elaborated in Chapter 7. This is intended as a generative metaphor that helps to complete an integrated view of information processes that are now dominated by the metaphors of transmission via channels, and of the management of information as a resource object.

Both of these results, the creation of a novel semantic space for organizing and visualizing relationships among concepts, and advancing a person-centered, cognitive view of information, resulted directly from a complex set of questions and dilemmas which first of all accompanied this research effort from the start, and which arose in the context of ongoing projects organized around efforts to find better ways to share data and information across organizations, groups and interests. The catalyst for the particular results derived here was an interdisciplinary effort involving earth scientists, humanists and practitioners, New Directions Downeast. The background of these contextual contributions is detailed in the Preface to this paper.

Question-Centered Learning Environments

A critical component that was explored in that context was the need for a space in the digital online environment where many of the interactions might take place that would be intrinsic to what came to be termed an interactive learning environment. Conceived initially as a conversation space to support discourse related to the development of a digital library for sharing documentation and data related to regional natural resources, this was reconceived as a question space that would accommodate the central concerns of participants. This question-centered space, intended to be an alternative to the more customary knowledge-based information systems, is detailed in the present chapter. An overview of the complexity of question asking and answering processes is included. This chapter reflects the motivations and goals that are meant to be addressed by means of the resonance metaphor and the heuristic workspace.

In addition, a simple example of how a narrative might be structured and represented within the proposed workspace is presented in Chapter 9. Summary conclusions and suggestions about future directions for this work complete the paper in Chapter 10.

Read together, the chapters in Part Two present an alternative design approach that is meant to complement, not replace, other more prevalent concepts and approaches to the design of information environments. Distilling the many concepts and metaphors for information that are elaborated in this work, we now suggest that an integrated view of information will include three primary aspects: communication, documentation and learning. These approximately correspond, respectively, to the transmission, resource and resonance metaphors. The suggestion is that a comprehensive view of information requires that all three aspects need to be represented in the design process.

As components of a design solution, these alternatives are reminiscent of what Christopher Alexander and colleagues (Alexander et al., 1977) call “patterns,” as used in

their pattern languages approach to design. He defines patterns as being the outcomes of forces that are at work in particular contexts, together pointing toward particular solutions, the transformation “from a set of forces to a form.” This concept of patterns is itself a pattern, a conceptual landmark that could qualify as being one of Rosch’s prototypical categories, the stable but not completely and formally defined concepts that are available to us while engaging in the sense-making that characterizes all of our cognitive activities. Conceiving of structures in terms of forces and contexts as Alexander does is a theme that is reflected in several of the authors cited here.

These alternatives for the construction of an information system result from an earlier exploration of questions centered on the spatiality of information sharing processes. This work largely involved participation in many discussions about digital information environments across various groups of practitioners, many involved in community-based use of spatial technologies or having interest in marine and other natural resource conservation and management issues. The discussions often referred to different communities or user groups, groups geographically based or defined by their commercial interests, values or ways of knowing, the coordination of which via information systems being presumed but the form of those systems very much in doubt. The need to bridge gaps across these communities and groups, the need for “common languages,” the need for “information” to be passed or accessed across these gaps and groups was constant throughout these discussions.

Puzzling over the many ways that these problems were stated led to a realization as to the importance of such existing patterns of thought as the pathways-to-knowledge and conduit metaphors. The scenario frequently discussed within New Directions Downeast, for instance, (see also discussion in the Introduction) began with the perspective of coastal and marine geologists, whose research results are being gathered into a collection of digital documents called the Marine Realms Information Bank

(MRIB). These scientists wanted to make the results of their work and expertise more readily available as resources for others among the general public, for instance residents of coastal communities those engaged in commercial fisheries. The overall goal would be to expand access to research results for those who might have need for them, in places where the results would find contexts for application to actual problems of resource management practice and policy.

Within this scenario, it was often asked, how could community information needs be identified? Who were the members of these communities of users? What “common languages” would be needed to help people from these communities in expressing those needs in terms that could be understood across communities? How could people, in effect, negotiate a path from their questions to the answers presumed to exist in other places, produced by other people for other more generally stated or differently situated purposes? Often implicit in the discussions was the notion that there are some people who know, and some who need access to what they know, and that these all need to communicate via a common language that no one yet fully understands. The development of this common language would seem to depend on the availability of a setting for the negotiation of shared meanings, a setting that also does not yet exist. In addition, as long as a distinction is maintained between those who know and those who need access to knowledge, the chances for creating such a setting and finding people to interact within it remained unlikely at best.

It began to appear that the framing of the problems would not lead in an effective way toward answers or solutions. This prior problem, clearly identified by Schön (1979) as one “problem setting,” can according to him best be addressed through understanding the “generative metaphors” that people bring to the problem solving situation. Much of the present paper has been aimed at examining some of the generative metaphors that are

now available to those who wish to design and construct systems for information sharing, toward the goal of expanding the available repertoire.

Within the scenario outlined above, questions such as the following began to be asked: Why not level the field (so to speak) and assume that there really is not such a great distinction between those who are asking and those who know; that although what each of the partners in this process “knows” may be expressed in words that are hard for others to understand, perhaps what each “does not know,” or their questions, might be easier to frame in mutually intelligible terms. Why not conceive of each partner as being a mix of questions and answers, that provide mutual context for each other, and that are both the basis and the consequences for questions and answers that have come before and will follow in time? Instead of conceiving the problem as one of pathway from questions to answers, why not conceive of constellations of questions that may be brought into closer proximity to each other? Why not initiate a process toward building communities of questions and those who are asking, rather than in emphasizing the (unequal) relationship linking those who have questions with those who may be in the know?

It was through the effort to visualize these newly conceived relationships, and to create an actual “space” within which they might be represented, that the outcomes described here were created. The presentation here is textual, the narrative form of a “chapter;” two-dimensional, via illustrations attached that are referred to from the text; and a three-dimensional / multi-dimensional navigable digital space which is described in the text but which needs to be demonstrated and used in understanding it. The idea of question-centered learning environments is mainly expressed in narrative form; the graphic image *This Corner of the World* (Figure 1) expresses the main ideas of the resonance metaphor; and the digital workspace is an approach to realizing the idea called “heuristic workspace.”

The purpose of the sections that follow is to evoke in the reader a sense of the whole through description of a set of integrated parts. Because all positive assertions vastly underdetermine the worlds to which they can be mapped, resolving uncertainties about the potential usefulness of the design solutions offered here will depend in some measure on the possible environments and contexts within which they are applied.

Reframing the Relationship between Questions and Answers

A desire to explore the concept of question-centered rather than knowledge-based information systems was among the initiating questions that attracted me to this program of study: “What distinguishes question-oriented from answer-driven information systems?” (Schroeder, 1995).

Asking and answering questions is a more complex process than is generally conceived. An ability to reduce our preconceptions about questions that are being asked, seeing them as expressions of a mix of knowledge and uncertainty, and knowing the range of possible answers that will satisfy the questioner are learned skills. Since each person asks and answers questions continuously in everyday life, increasing the repertoire of skills and available contexts within which these can be applied should be part of the task of those interested in creating effective information systems design. A question-centered approach is also person-centered, maintaining the assumption that each person is in some measure a combination of questions / uncertainties and answers / knowledge. In these terms, all knowledge depends on pre-existing questions, and all answers lead again to new questions.

Dervin and Dewdney (1986) suggest that people who seek to become more effective in questioning and answering should adopt a particular form that they call “neutral questioning,” that serves both to clarify questions and to keep choices of outcomes open. Neutral questions are midway between closed (one answer, either/or

questions) and open, nonstructured questions. They explain how this approach is helpful in exploring the three core elements of sense-making: situation, gap, and use. Dervin also identifies a set of “help categories” that aims to keep choices open in what is always a dynamic question answering process. She enriches our notion of “answers” with such concepts as “creating ideas, finding directions or ways to move, acquiring skills, getting support or confirmation, getting motivated, getting connected to others, calming down or relaxing, getting pleasure or happiness, and reaching goals” (Dervin, 1992, p. 75). She further states (1999, p. 44) that the questions always express “an incomplete understanding of reality (ontology) and an incomplete understanding of what it is to know something (epistemology)” leading to the challenge of how to bridge various gaps. This activity, which requires a strategic approach, is not simple. We must “make sense without complete instruction in a reality” and also must “reach out to the sense made by others . . .” (p. 45). These examples show that even unproblematic questions may imply a complex range of appropriate responses. It seems that a place where this sort of activity, all the dimensions of an individual’s “situation stops” (Dervin, 1992, p. 75) could be gathered into one image, structure or form, would be a “question space” such as may be required for a question centered learning environment.

Acknowledging these sources and general statements of the problem, the remainder of this section will discuss the dimensions of questions, generally, and will introduce aspects involved in building a question-space, or place, that might serve the requirements of a question-centered learning environment. This could also be considered to be an approach to creating a digital environment that shares, if only partially, in the character of a discourse space or a conversation space (Krippendorff, 2002), always involving people in their human presence, where legitimate questions can be made visible, where shared meanings may be negotiated, and where each person or community has the opportunity to take responsibility and control over their own representations.

Imagining an alternative question-centered approach, we can assume that all who are involved (the public citizen as inquirer, for instance, as well as the research scientist who has results to share) are motivated by questions; and all who are involved also to some measure already have answers.

The strategy of approach in a question-centered model could be toward the self-identification of communities of questioners, in which the shared positions and frames of reference are found by means of, or implied by, the relative proximities of the questions that are asked – finding a way to situate the motivations of the scientist, for instance (which are often not made explicit) near to the motivations of the public citizen. Given that an important element in the creation and design of digital libraries is some understanding of the communities to be served (Waters, 1998), one way to redefine these communities would be through a process of identifying “communities of questions,” that certainly would cut across existing notions of the personal and social identities of those who are potentially involved as participants.

The first advantage that this approach has is it challenges the idea that someone, generally the nonspecialist, is the one who “needs” information; and that someone else, generally the authorized expert or that person’s documentary or database surrogate, has “the answer.” Scientific results can instead be explicitly considered as formalized expressions resulting from a community of questions – into which others may be invited to join; or which might find itself in proximity to other communities of questioners. The commonplace would no longer be: to every question its answer; but rather: to every question its community of questioners. This approach is in line with the emphasis on “discourse communities” advanced by Jacob and Shaw in their “sociocognitive” perspective on information (1998, p. 141 ff.).

The sections that follow explore some characteristics of questions, generally, and begin to suggest a strategy toward removing the apparent distances between questions and answers, creating a new field that accommodates both within one proximate space.

The Complexities of Questions

An overview of what questions are, situating questions in the context of our everyday activities, is needed in order to begin to structure a place or space for questions, or in attempting to reframe the question asking and answering process. The notion of questions seems to be relatively unproblematic, but is not. Norman (1972, p. 2) reminds us that a “wide variety of cognitive capabilities are involved in dealing with this deceptively simple part of our everyday activities.” He claims that “considerable preprocessing precedes question answering” including the exercise of the following skills: “simple inference; knowledge of causality; understanding of physical laws; general knowledge of the world; understanding of what the person asking the question already knows” (p. 3). To answer a question properly “requires that the respondent understands the requirements of the person who asked the question” (p. 25). “In order to answer a question appropriately, it is necessary to have a model of the knowledge of the listener, including knowledge of why the question was asked” (p. 26).

Difficulties in simply identifying a question as such is recognized in the branch of linguistics concerned with speech acts. Questions might be directly addressed with the purpose of getting an answer, but “this is not the only thing that one can do in expressing a question” (Huddleston, 1994, p. 3845). There can also be answers revealed, when there may have been “no implication that any act of inquiry took place” (p. 3846). These complexities alone should caution in trying to extract “what exactly is the question” from open-ended (or, in the present case and Dervin and Dewdney’s terms, “neutral”) question exploration settings.

Huddleston explains that the most general sense, the English language has two subtypes of interrogative, “closed” and “open” -- the first being of the yes / no, this / that, or and “or-coordination” such as “‘alive’ and ‘dead’” (p. 3849). For “open” interrogatives other terms and concepts may be substituted, such as “‘information question,’ ‘special question,’ ‘partial question,’ ‘question-word question,’ ‘*wh*-interrogative/question’” (p. 3850). To these, answers are generally open-ended, though available choices may be implicit in the way the question is asked. These are the questions involving who, what, why, etc. These sorts of questions are commonly held to have implicit presuppositions - if it is a who question, there is assumed to be a “who” out there that satisfies as answer to the question.

Even when we are assured that a question is being asked, in any of its many forms, a recognition of the underdetermined nature of language must be kept in mind throughout the question asking and answering process. The resulting ambiguities are not all “negative.” They explicitly require that the listener is asked to engage in work, or participate, in meaning creation, the essence of the theme of action orientation to information. Ambiguities provide a margin of dynamic creativity that allows language to work at all.

The role of context in resolving ambiguities that accompany all expressions, including questions, are explained by Hall (1976, p. 74) in the following terms. “The problem lies not in the code but in the context, which carries varying proportions of the meaning. Without context, the code is incomplete since it encompasses only part of the message.” He further illustrates by saying that language abstracts events which can never be encompassed by the language. He presents the three dimensions of meaningful communication: “in real life, the code, the context, and the meaning can only be seen as different aspects of a single event” (p. 79).

An example that makes the importance of context very clear is in the tale Nørretranders tells (1991/1998, p. 91) of an exchange between Victor Hugo and his publisher. “The shortest correspondence in history took place in 1862. Victor Hugo . . . had gone on holiday following the publication of his great novel, *Les Misérables*. But Hugo could not restrain himself from asking how the book was doing. So he wrote the following letter to his publisher: ‘?’ His publisher was not to be outdone and replied fully in keeping with the truth: ‘!’ As The Guinness Book of Records says of the publisher’s reply, ‘the meaning was unmistakable.’” Nørretranders calls what is left out of the message “exformation” (p. 92) and says that creating a short message with great depth needs much “mental work” to take place. “It was not the number of bits transmitted that was decisive, but the context of that transmission.”

Understanding the importance of context, including cultural context (or the contexts of interpersonal or intercommunity differences), points toward the need to preserve contextual settings for questions. A designed question-space would be context-preserving.

How can these observations be translated into something like a map or mental model of a question space? A multidimensional coordinate system for social/cognitive maps can conceivably be developed, onto which any person can establish a place for his or her question. Responsibility rests with the active inquirer. Because every person, from his or her own perspective, has limitless “knowledge,” to situate oneself on a knowledge map might be an insurmountable problem. The task might become more tractable on a question map. This mapping might be assisted through the use of an array of pre-established question discovery templates, formally based on theories and typologies of questions.

Questions Considered as Design Problems

The preceding paragraphs have indicated many of the complexities involved in the asking and answering of questions. How can questions be viewed so that these complexities are organized so that the processes that are initiated when a question is asked may go forward in spite of lack of clear definition of all aspects of what is going on? The range of uncertainty that is involved goes well beyond the uncertainties embedded in the subject of particular questions, and their resolution is part of the process of sense-making that characterizes all activities involved in communication and cognition.

It may help both the questioner and those who are addressed to think of questions as being constructs or compositions that are situated problem solving devices, designed in an ad hoc manner and aimed toward resolving uncertainty. Questions express contexts, have force, and point toward potential answers or solutions. In these aspects questions are structured in a way that is similar to Alexander's patterns, the elements of his approach to design.

Viewed as patterns, motivations and situational contexts may be seen as being integral to questions; and answers (however defined) must acknowledge the questions / patterns as a whole. Answers need to address the complex sets of forces that questions express, forces that may even be unknown by those who have brought the question forward. Creating a space within which the multidimensional nature of any question can be represented, with room for the many forms of unknowns, might help in accounting for all of the forces that are involved. This in turn may provide opportunity for solutions, or answers, that may not otherwise become apparent.

Thinking of questions as constructs that are aimed to resolve interacting forces also helps us to see that questions are expressions of a disequilibrium, sometimes unsettling but potentially productive when viewed as creative disequilibrium. Considered

in terms of the resolution of forces, the stability attained through arrival at an answer is never permanent. The results are immediately then introduced into a new spatial / temporal / material / cultural context (or situation, chronotope) that itself begins the process of instability, creative disequilibrium again.

Some Current Approaches to Question Answering in Digital Environments

The notion of question spaces that is presented here should be considered along with existing approaches to the management of questions in today's increasingly digital environment. This section reviews some of the approaches that are now in place or under development.

Brandt examines changes in library reference service that are results of the rise of online digital technologies, with particular view to the needs of users, their mental models of systems, the capacities of solutions that are in place, and how these may serve a model of learning based in a constructivist paradigm. "Resources modeled after AskJeeves use a fairly simple data engine to serve up facts such as units of measure, but have a long way to go to actually interpret complex questions, let alone provide answers to them" (Brandt, 2001, p. 39). He contrasts the librarian's "mental model of reference, or information querying" with that of users and asks, why do people "have problems articulating their reference questions? Do they have a system model for the organization of reference resources? What mental models do they use to solve information problems in a networked and information rich environment?" (p. 43).

In the realm of public reference services that are associated with libraries, the U.S. Library of Congress (2003) has taken initiative in the form of its Digital Reference Initiative, and the U.S. Department of Education (2003) has a parallel effort in its Virtual Reference Desk, an initiative related to the ERIC Clearinghouses of educational documents and research.

The opportunities for providing direct reference service, especially to the K-12 education community, are known as “AskA’s” as in, “ask a librarian, ask a mathematician, ask a geologist.” Lankes (1999), who is affiliated with the Virtual Reference Desk effort, summarized these services and reviews their potential for success. Using the concept of “anomalous states of knowledge” as conceived by Belkin, Lankes asserts that “The user’s anomalous state of knowledge is operationalized as a question that needs to be answered” (p. 63). He states that queries are directed to a system, and in “digital reference services, all information is delivered to a user electronically.” Note that the model he uses is one in which all interactions are via digital media, and that information is conceived as something that can be “delivered” to users electronically.

Lankes reviews implementations of online question-answering systems, noting that many managed workflow through use of PERL-based forms and other scripts. His own contribution to online question management is through the development of a metadata standard, called Question Interchange Profile, or QuIP. This is intended to be “a means of representing threads of questions and answers in an electronic record” (p. 68). QuIP includes components that reflect the conditions of the question (called, “transaction wrapper”) a metadata representation of the question, full-text representations of the questions and answers, and profiles of users. Overall, QuIP creates an object that may be used outside the particular question setting from which a QuIP record has emanated. QuIP may be seen as “foundation for cooperative support and reference services” (p. 69) and the use of QuIP might facilitate the creation of incentives, including cash payments, for participation in digital reference services. It allows routing of questions, and may have application in private services such as computer software support, allowing transfer of questions from vendors to third party producers.

It is clear that already there are already many choices for users who want to pursue the answering of questions online. Aside from general search engines for sending

queries to the World Wide Web, there are a number of collections of reference materials that have been gathered specifically to help organize questions into the framework of available reference resources. These include the Library of Congress' Virtual Reference Shelf, the Internet Public Library, the XRefer collection of digital reference works and the WWW Virtual Library, in addition to the specific services and initiatives aimed at managing questions such as the AskA services and QuIP metadata protocol outlined above.

Conclusions for the Design of Question Spaces

Overall, the collections and services mentioned above are built around the availability of existing resources, and can be viewed as knowledge-based rather than question-centered systems. They preserve the notion of information as being made up of objects that exist independently of the persons who use them, available for transport once identified, and in this way fit the existing models and expectations of users of information systems including libraries. There is no question that further effective and efficient development of resources such as these will be welcome and important enhancements to our information environment conceived in terms of information resources.

The alternative that is being proposed in this section attempts to address the questioning process without depending on assumptions that operate in correspondence with the pathways-to-knowledge and conduit metaphors of information. If we cannot travel to our information objectives, and if information is not an object that can be brought to us, how could a system be conceived that still might meet the needs of questioners, that in fact puts those needs and the forces that interact to produce those questions into the center?

Instead of directing primary concern toward the management of knowledge, the identification of who may have it, how to gain access, and interoperability of knowledge-management systems, why not conceive of all knowledge as being the embodiment of sets of originating questions?

Questions may be much simpler to manage than structures of knowledge, and it may be more efficient to focus on the formulation of questions than to focus on the management and identification of knowledge. Questions can be considered to be an abstraction from the world of knowledge. The creative disequilibrium that questions represent is a central motivating factor in people's participation in information systems. Putting this motivation to work in creation of "communities of questioners" may be a more interesting, and more effective, way of organizing the many problems that accompany the posing of questions, as outlined in the paragraphs above.

There may be a problem, largely unacknowledged, with knowledge-based information systems in that they are organized around answers that were based in contexts and motivations that are prior to the new questions that are being asked. There is an assumption that these pre-existing answers are transportable into new question situations. This assumption may not hold as consistently as is usually supposed. For instance, Clark (1993, p. 91) calls attention to the work of Barsalou (1987) in these terms: "Heraclitus famously claimed that we can never step into the same river twice. Lawrence Barsalou makes a similar claim about concepts. Barsalou seeks to challenge the received picture of a concept as a basically invariant structure which explains set membership and typicality judgments. His skepticism is based on a series of results which show that such typicality judgements (the Rosch-style graded membership cases . . .) are surprisingly unstable across contexts."

The potential for imagination, innovation, creativity, growth and emergence of the new is not the main objective for knowledge-based systems, thus closing many of the

opportunities that should be present or expected to be available when something as simple as a question is asked. Focus on data, facts and answers means being closely tied to the world of “is,” while questions ideally open the possibility of conceiving the world “as desired.”

In addition, knowledge based systems are left with the problem of organizing the universe of knowledge, an endless task, leaving no place for paradox, ambiguity, incommensurability and the genuinely unknown. Because these cannot be “managed” by knowledge-based systems, they are not included in the world of possibilities when something as simply complex as the asking of a question is performed. When the existence of uncertainty is taken seriously, then questions will point toward a fundamental condition that is often ignored in the question situation from the start. Because we usually negotiate our everyday discourse without much effort, we may need frequent reminders that fundamental uncertainties are implicit in all symbolic expressions, whether presented in the form of questions or not.

The motivation for rethinking the concept of the information sharing situation arose from situations in which the distances of interest, motivation, worldview and language are large. Can these gaps be bridged through refinement of categories and improvement of interfaces, providing more transparent access to information products of scientific research? In some measure, yes, but a more interactive approach seems needed.

To the extent the problem to be solved includes an environment for the mutual negotiation of meanings that would bring many different communities into mutual understanding, the refinement of information management and access systems as traditionally conceived will not be sufficient. If all participants are recognized as possessing knowledge and questions in some measure, and if it is assumed that the evolution of knowledge and the emergence of significant questions depends on two-way interaction, why not think of questions as abstracts of the forces at work in any existing

knowledge structure? Then, questions might be brought into closer proximity to each other, allowing alternative choices for satisfactory answers to arise from a negotiation, or dialogue, among those who have raised them. Attention to questions in this way may be an efficient, though indirect, way to organize vast information resources, including the motivations and goals, situations and contexts of questions and answers.

Focus on questions also might allow people to remain within their own terms and frames of reference, rather than being compelled to adopt preexisting or universal knowledge frameworks within which to “navigate.”

The following chapters build on these general thoughts about questions, and situate them within an alternative “resonance metaphor” of information, that accommodates structures of forces as well as objects, and suggests how a strategy of bringing questions into proximity, and creating communities of questioners, might be achieved through the creation of new kinds of space. The “heuristic workspace” described below is offered as a candidate.

Chapter 7

A RESONANCE METAPHOR FOR INFORMATION

This section suggests a “resonance metaphor” for information that is meant to complement the two more familiar metaphors detailed in Chapter 2, the “conduit” metaphor for communication and the “pathways” metaphor for learning. These metaphors also dominate our images of question answering processes. While the conduit and pathways metaphors, along with the transmission and natural resource concepts, all seem to go together in creating a mutually consistent picture or image of information in its spatial, structural and process aspects – a consistency based in their locating of information objects and processes in the outside, material world, making information available independently from any particular person’s perceptions and uses – our focus on a third view involves a sort of figure-ground shift, placing strong emphasis on the participation of human cognizing subjects as being integral not only to the information process, but to determining when information has been brought into existence.

This section completes the discussion opened above in the section on imagining alternative metaphors in Chapter 2 by elaborating one that seems to be consistent with the constructivist view of information. The absence of such a metaphor seems to be one factor that has prevented the person-centered notion of information from taking hold as an effective complement to more data-centered approaches. Once this metaphor (or image, or concept, or pattern of relations) became clear, many examples of the use of resonance metaphoric thinking were identified and became available as examples. The origins of this idea and elaboration of its implications through various examples will occupy the rest of this chapter.

Initial Visualization: *This Corner of the World*

The previous chapter, proposing the construction of question-centered learning environments to complement knowledge-based information systems, provided a rationale for thinking about asking questions and solving problems in a way that tries to avoid the implications of movement that are embedded in the conduit and pathway metaphors. The suggestion here is that, in thinking about information processes, we put a temporary hold on the notion that as questioners we “go to” a place where knowledge may be “found,” as well as the idea that information which we may need is somehow “delivered” to us. If we can engage in essential information processes simply by sitting still, what sorts of relationships and processes might actually work toward satisfactory results in terms of the problems and questions that motivate action in an informational context?

In part a solution was suggested in terms of “proximities.” Rather than traveling from a region of uncertainty to a place of knowledge, and rather than bringing knowledge in the form of objects to complete a local work in progress, we conceived of a space in which questions and answers, or uncertainty and knowledge, are considered to be interdependent wholes, characterizing all participants in the information process. The task then became how to effectively bring these question and answer complexes into some relationship on a “level field.” It was hypothesized that focus on questions might be a more efficient way to abstract any particular participant’s status in this learning environment. How these proximities, fields and stable (non-moving) situations might be visualized, and then operationalized, was not addressed.

The resonance metaphor presented here, and the graphic image that evoked it (Figure 1), provided an integrating structure for much of the discussion that went forward in the Orono component of the New Directions Downeast project. Discussions that framed the creation of this graphic occurred in July and August, 2002 (discussion summaries are available online, see New Directions Downeast, 2001-2003). Presentation

and discussion of this graphic among the entire NDDE project occurred at a meeting in Rye, New Hampshire in September, 2002 (New Directions Downeast, 2002) is included at the end of the summary of the Rye NH meeting of Sept. 7, 2002. The presentation and discussion of the graphic at that meeting led directly to the concept of a “resonance metaphor.” A summary and extracts from these discussions that outlines the ideas that the graphic was meant to evoke and points toward the overall results reported have been provided in the Introduction.

From *This Corner of the World* to the Resonance Metaphor

Although the graphic *This Corner of the World* was thought to be a good candidate to express the various ideas that had been discussed generally within the topic of coordinating questions, it was a nearly random connection offered during the presentation of the graphic in Rye that opened the possibility of linking the graphic to a consistent set of theoretical considerations about information processes generally, particularly the concept of “dissemination” of information.

How the graphic was conceptually linked to the work of Sarah Michaels, particularly in terms of information behavior that evokes the concept of “reverberation, is recounted in the Introduction. Michaels’ concern was with the dissemination of natural disaster information, particularly earthquake information (1992). How does information actually travel, and in what forms, among the many people and institutions that make up the constituency for natural disaster earthquake information? These include scientific researchers, land use managers, building code enforcement officials, and many others including the general public. Whereas some information is general and is used in policy making and disaster preparation, other information is very timely, specific to emergency situations. She contrasts an “information issue networks” model with the more customary “producer-user” model. The issue networks approach critically evaluates the notion of

stable roles for information producers and users and suggests a more dynamic set of information relations (1992, pp. 160-161).

Michaels bases her adoption of an issue networks approach on the work of political scientist Hugh Heclo, who “characterizes issue networks as a voluntary and fluid configuration of people with varying degrees of commitment to a particular cause.” Not only are roles fluid, often several networks are interacting simultaneously. In terms of her investigation of natural disaster information, particularly earthquake information, many networks make up the “earthquake policy community,” from scientists who publish in technical and research journals to those many people involved in disaster management who are not part of the scientific “information web” (p. 162). Much important communication takes place outside “formal participatory arrangements,” thus minimizing many formal transaction costs (p. 163). Viewing the earthquake policy community as a whole, Michaels states that “information does not flow through such communities, it reverberates among various nodes of the networks and often gets lost along the way” (p. 161).

Her single use of the word “reverberates” remained with Marincioni as a particularly apt term to describe the informal intersecting processes that were identified by Michaels. Her article did not include a graphic to illustrate the process she had described. Yet the relationships and processes described by her fit well the kinds of relationship we were exploring as our own graphic emerged. It should be noted that the way our discussions were connected to Michaels’ work, through a mental comparison made by one person between a graphic image and the presentation of a theory in a text, fits with Paivio’s “dual coding” approach to memory involving language and images, discussed above, and also is a demonstration of “small world” effects that often have much more importance in the actual operation of information dissemination processes than would be apparent from the structure of formal information systems.

Other Expressions In Keeping with the Resonance Metaphor

Once the notion of resonance entered our vocabulary, many examples in which these words conveyed meanings similar to those we were striving to express were noticed. Some of these disparate contexts, perhaps united only in their evocation of a nonlinear process of communication and understanding that finds expression as resonance and reverberation, are summarized in this section. These examples show that as a way of speaking, the resonance metaphor is a common form of expression. Relating them here is intended to make a broader sense of the scope of this metaphor available to the reader, and to relate its use in the domain of information processes to other contexts where the metaphor serves a similar role.

The examples begin with Roediger's survey of memory metaphors (1980) that has been detailed in Chapter 2. Most images for memory involve images of actual spaces and the objects that are in them. Among the 36 memory metaphors he describes he claims that "no other general conception of the mind or memory" that rivals "the conception of the mind as a mental space in which memories are stored and then retrieved" (p. 238). With particular relevance to a resonance metaphor, Roediger identified three analogies "based one way or another on auditory imagery" (p. 240). Roediger states that the "basic idea of retrieval as a matching or resonance process has been used by a number of . . . psychologists." For some, retrieval is compared to "the operation of a tuning fork. When a tone of a particular frequency is sounded in the presence of a bank of different-sized tuning forks, the appropriate one will vibrate sympathetically" (p. 241). In everyday speech, we might say that a retrieval cue "rings a bell." Roediger observes that resonance models may be "formally identical to spatial storage and search theories if one assumes an unlimited capacity, parallel search process (p. 241).

Anthony Judge (1996) questions the adequacy of the “highway” metaphor for the “emerging information society” and suggests as an alternative the “songlines” of the Australian aborigines. Songlines define pathways for members of the indigenous culture, allowing travel across great distances over lands occupied by different language and tribal groups. Each person only holds a portion of a songline. Relying on Chatwin, Judge states that the “land first exists as a concept in the mind and is given form through the singing” that brings the landscape into existence. He considered this to be a “fundamental act of creative aesthetics” (p. 8 of 10). This also represents an entirely different way of conceiving of the ‘land’ and landscape than ours. Referring to geographer Yi-Fu Tuan, Judge introduces the concept of resonance. “Hyperlink pathways could also be used to map out patterns of resonance between the points of significance in a poetic construct. For it is possible, as with certain chemical molecules (resonance hybrids) that certain configurations of insight could only acquire stability as a gestalt by resonance of their parts between quite distinct alternative structures -- the dynamics of resonance providing the basis for stability rather than any one of the particular structural configurations of pathways (all of which may be unstable). Yi-Fu Tuan says of resonance in aesthetic context: ‘Experience, unless it carries resonance, is shallow and transient. Resonance is the result of the extension of one field of meaning to another -- a change and enlargement of context so that a phenomenon is more than how it first appears. What makes resonance possible is the human capacity for metaphorical perception and thought’” (Judge, quoting Yi-Fu Tuan’s *Passing Strange and Wonderful*, p. 30, at p. 4 of 10).

The connection that Judge and Tuan suggest between songlines / resonance and our connection to the land reminds of Spitzer’s classic work, analyzing the German word *Stimmung* (1963). He claims that “what is missing in the main European languages is a term that would express the unity of feelings experienced by man face to face with his environment (a landscape, nature, one’s fellow man) and would comprehend and weld

together the objective (factual) and the subjective (psychological) into one harmonious unity” (p. 5). “For a German, *Stimmung* is fused with the landscape, which in turn is animated by the feeling of man -- it is an indissoluble unit into which man and nature are integrated” (p. 5). There is also the notion of *gestimmt sein*, “to be tuned . . . which in its inference of a relative solidarity or agreement with something more comprehensive (a man, a landscape, is tuned *to* ‘something’), differentiates it from *state of mind* . . . and presupposes a whole of the soul in its richness and variability . . .” (pp. 5-6).

Judge’s reference to Australian songlines also reminds us of the traditional methods of navigation practiced in Micronesia, where essential information literally comes in the form of propagation of waves. The example of South Sea navigation is used in many works devoted to maps and cartographic practice. Hutchins has studied navigational practices aboard modern naval vessels as exemplary of cognitive processes (1995). He also studied indigenous navigational practices in the Caroline Islands, and illuminates many of the hidden assumptions that separate western from traditional navigational practices. These included reliance on diverse information sources, including color of water, local swells, swells interacting with islands, winds, birds, and stars (Hutchins, 1983).

Edward T. Hall, whose work explores relationships between space and culture at various scales (his science of proxemics), provides a chapter on “rhythm and body movement” (Hall, 1976, pp. 61-73). Hall reports the observations made by William Condon, who by means of frame-by-frame analysis of films studied people moving together when interacting. Condon found that verbal behavior and movement are often closely synchronized, as in performance and dance. He quotes Condon in recommending that our image of people as “isolated entities sending discrete messages” (p. 63) should be abandoned in favor of a bond that is “the result of participation within shared organizational forms. . . . This means that humans are tied to each other by hierarchies of

rhythms that are *culture-specific* and expressed through language and body movement” (p. 64).

Pratt’s essay on the work of Gestalt psychologist Wolfgang Köhler, notes that Gestalt perceptions that cannot reduce wholes into discrete parts include “contours, the various constancies, chords, melodies, speech, rhythm, diminuendos and crescendos, etc. Such phenomena are Gestalten, not sensations, and they have their own laws and methods of investigation that have little resemblance to the principles and procedures of classical psychology” (Pratt, 1969, 21-22).

A memorial address given recently at the University of Maine by historian Joan Wallach Scott, titled “Feminist Reverberations” (since published, see (Scott, 2002)) identified the word reverberation as one way to begin to understand the significant global links that are being made by small, local groups who are only affiliated in informal, nonhierarchical but nonetheless powerful ways. After describing an increasingly fractured world, and suggesting “echoes” as being a metaphor for certain forms of global awareness, she suggests that “in these days of cataclysmic transmission, it would be better still to talk about reverberations, seismic shock waves moving out from dispersed epicenters, leaving shifted geological formations in their wake. The word reverberation carries with it a sense both of causes of infinite regression--reverberations are re-echoes, successions of echoes--and of effect--reverberations are also repercussions” (p. 11).

A specific example she gives is the movement called Women in Black. These groups have autonomously appeared in many settings around the world, standing variously for end of occupation of Palestine, against mafia, against neo-Nazi violence, against “religious fundamentalists’ mistreatment of women” (p. 16). Overall, they are “an improvisational strategy, locally deployed, but not as a branch of any centralized association” (p. 17). Most importantly, the Women in Black movement does not presume sameness among feminisms, but “presumes fundamental differences among feminists,

differences of context, differences of history, differences of understandings of the feminine and of feminism itself” (p. 19). “The reverberations of feminism have not usually been earth shattering, but they have created all kinds of disturbances, laterally and longitudinally” (p. 20).

Many other examples have been collected since our attention was directed toward resonance aspects of human interactive process, including information. The examples above are provided in order to establish that their place in a total concept of information is not idiosyncratic here.

Summarizing the Resonance Metaphor

The potentials that may be available through adopting a “resonance metaphor of information” emerged as an unexpected solution to a set of problems that were being resolved among participants in an interdisciplinary project, New Directions Downeast. In that project, the idea of creating a digital library was generalized by some participants to encompass the notion of an interactive learning environment, within which the information needs of participants from many different user communities might be served through processes of mutual awareness and negotiation of meaning.

Both predominant metaphors for information process, conduit and pathway, evoke movements in the external world, either in the form of information objects that traverse time and space, from places of storage to places of use, or in the form of information seekers who traverse paths in their quest. Shelving these, at least temporarily, the problem was set as one of having something happen to create the possibility of change, in informational terms, without having to conceive that movement of objects is needed to effect this change. The notion of wave propagation was adopted as a way of allowing movement, but a very different sort of movement, as the basis for the representation of information process and change.

A spatial characteristic implied through this metaphor, in addition to introducing an alternative sense of how movement may be conceptualized in our understanding of information processes, is the appearance of centrality, of a center or centers. Though the conduit and pathway metaphors imply the existence of places and of movements across and among these places, resonance can be taken to imply a place of origin from which the resonance emanates. This is inherent in the image of a pebble tossed into a pond, as the initiating act of inquiry or questioning. The waves that travel outward imply the center from which they have come. Whereas the conduit and pathways metaphors can be conceived as being situated in limitless networks of an infinite universe, one can conceive of a stable and centered directionality by means of the resonance metaphor. Because there may be multiple resonant events simultaneously present (as already implied in the graphic *This Corner of the World*, Fig. 1) a possibility arises of coordinating the relationships among multiple resonant events, conceived in terms of standing waves or harmonics. This centeredness is represented in the structure of the workspace described in the next chapter.

Once identified, the resonance metaphor was found to be commonly used for interactive processes among people in many similar settings. It was often associated with words that are auditory rather than visual (especially as relating visual perception with a world of space filled with objects). Such words and phrases as harmony, in tune, rings a bell, vibes, echoes, pings, standing waves and so forth are related expressions of this concept.

Also of importance is the affordance given via the resonance metaphor in terms of the constructivist view of information described in Chapter 2. An essential perspective given by those who hold to this idea is that information does not exist at all unless it is perceived by a human subject. A concise statement of this perspective is given by Wilden (1987, p. 76): “Information may be symbolic, imaginary, or real and does depend for its

existence on being perceived by living creatures or human minds or senses.” This is an action orientation to information, and points toward the ways in which information always involves creative acts. People create order through the constant processes of sense-making said by Dervin to characterize our information activities. She theorizes (1999) that information “is made and unmade in communication” thus we must “create an information system to assist people in designing their own information and in particular, in sharing with each other the ways in which they have struggled individually and collectively to both create order out of chaos and create chaos out of order when order restricts or constrains them. . . . The system would allow not only the factizing that permits regimentation as a sometimes useful way of making sense but also the myths and storytelling that permit us to tolerate and muddle through diversities and seeming incompletenesses” (p. 43).

In this way, an information environment that is conceived as being made up of loci of mutual resonance may point toward the opportunity for perception, conceived primarily as active listening, to be the occasion for creative acts, the necessary though often unacknowledged negentropic attitude taken by people in our world. Information, as resonance, brings nothing to the perceiver except a signal that an act is required. This frame may be helpful in resituating responsibility for the existence of information in the person of the cognizant human subject. The concept of listening also reminds us of a set of factors that is important in all reception of information: attention, receptivity, the readiness to listen. Placing the information process in a frame that emphasizes listening may make us more able to enhance the receptivity and readiness aspects of information processes.

Chapter 8

STRUCTURING A MULTIDIMENSIONAL HEURISTIC WORKSPACE

This chapter describes a digital space that has been structured in a way that is intended to be consistent with the person-centered approach to information as well as the resonance metaphor. The structure is composed of three nested polyhedral forms that are arranged around a common center. These forms are translations of three figures that already are well established: two regular polyhedra (cuboctahedron and icosahedron) and a “tensegrity” that shares some characteristics with the other two forms as well as with the octahedron. The figures on which this structure is based can be physically modeled, and physical models of each were constructed prior to creating the structured digital space. The final configuration as based on such physical models is shown in Figure 3. In addition, there are some aspects of these figures that are not visible in the physical models. These nonphysical elements including center, central angle vectors and redundant chords are illustrated in Figure 4. This new structured space is the most tangible outcome that is presented in the present work. It is termed a “multidimensional heuristic workspace,” and will usually be referred to simply as “the workspace.”

This structured workspace organizes an otherwise undifferentiated space that is available in an existing software application, the Axon Idea Processor (Axon Research, 2003). After a briefly review of some of the motivations that led to the creation of this space, some of the primary characteristics of Axon’s generic space will be described. Then, the specific elements that make up the digital structure will be enumerated and described, followed by elaboration of some of the various conceptual relationships that might be represented in terms of the structural relationships provided here. The chapter will conclude with a summary of the characteristics of the workspace in terms of future development and in relation to perspectives of other researchers.

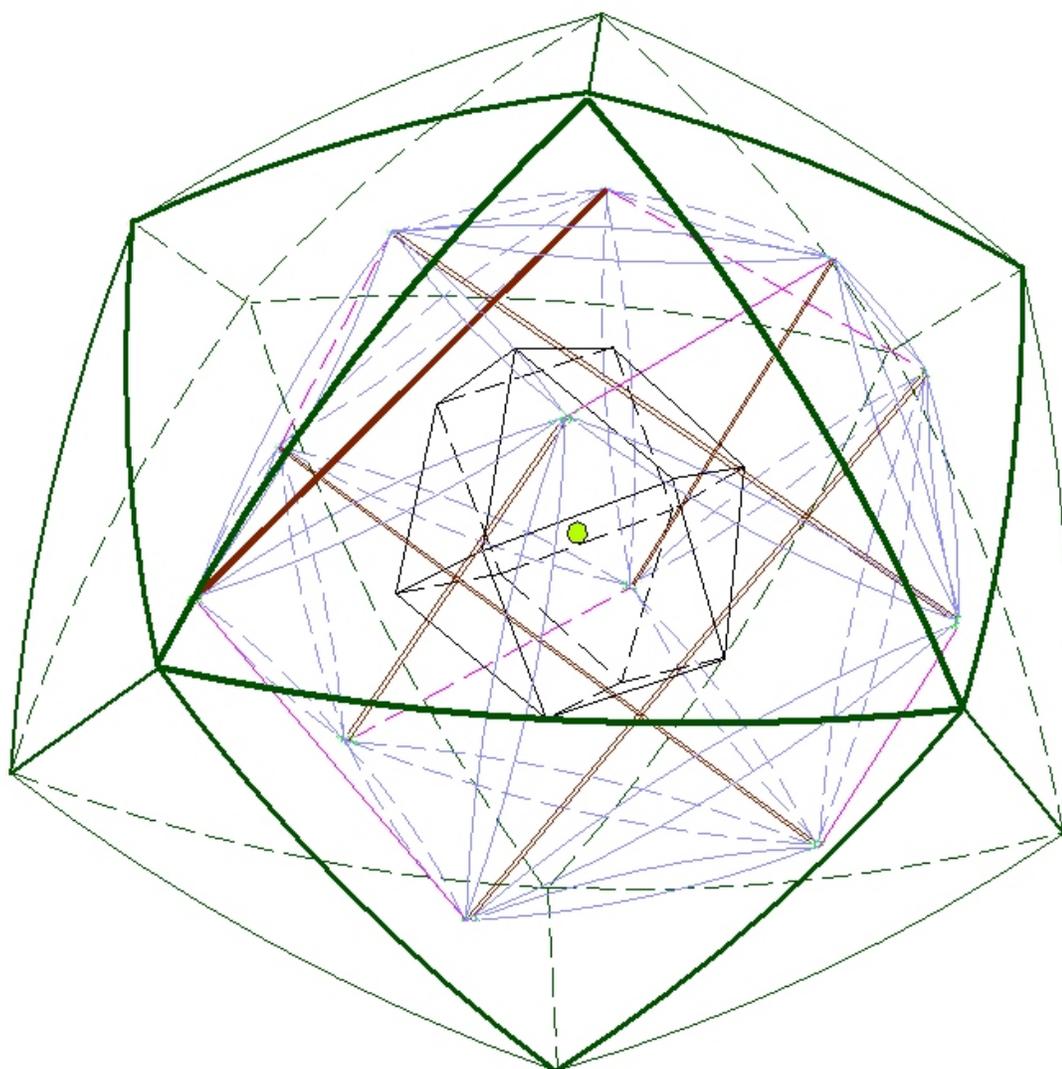


Figure 3. Overview of the workspace structure. These include cuboctahedron, expanded octahedron tensegrity, and surrounding icosahedral “context sphere.”

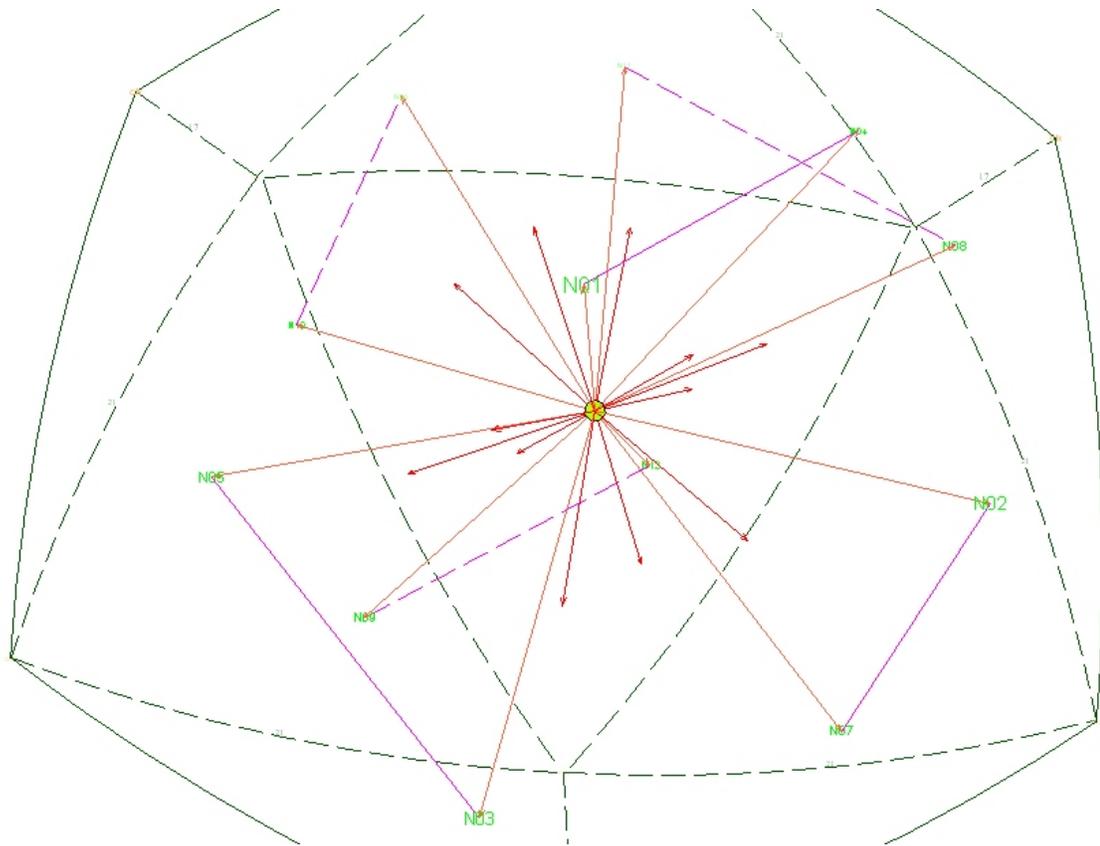


Figure 4. Nonphysical elements of the workspace structure. These include the center, central angle vectors to vertices of the cuboctahedron and tensegrity, and redundant tension elements.

Motivations for the Design of the Workspace

This space suggests a solution that attempts a synthesis of the problems and perspectives that are outlined in the preceding sections. It is intended to provide a setting where the concepts of “question-centered” and “resonance” can be operationalized. It is distinguished from most of the preceding discussion in that it is a real space, not a metaphoric space or theoretical narrative. As such, its characteristics, properties, and affordances may be easier to demonstrate than to describe in narrative form.

The same generative metaphor stands behind this workspace as that which led to an appreciation of the metaphoric role that resonance offers: consider that asking a question might be like tossing a pebble into a pond. This space resulted from a desire to solve the problem of representing that metaphor graphically in the most open and robust manner, allowing for full expression of the multiple dimensions that are implied by it. Because the workspace includes three nested figures that are each three-dimensional, all of which can be viewed simultaneously, this can be considered to be a multidimensional rather than a three-dimensional space.

The convergence of two sets of problems led to the creation of this space. The first was an ongoing attempt to display the meaningful relationships among terms that characterize space and information sharing as discussed in a set of open-ended interviews and small group discussions. This set of terms is given in Appendix A, and the project within which these texts were collected is summarized in the background section of the Introduction. These code terms have now been organized progressively in linear, network and three-dimensional arrays, the last of which is supported within this workspace.

The second primary source suggesting this solution arose from needs of the New Directions Downeast (NDDE) project. In particular, there was a desire to visualize a kind of space that might supplement the document access and retrieval functions of a proposed distributed digital geospatial library, the Marine Resources Information Bank (U.S.

Geological Survey. Coastal and Marine Geology Program, 2003). Again, some background about the NDDE project are provided in the Introduction. The conceptual relationships of the suggested online space, variously conceived as a conversation space, a question space, or an interactive learning environment, were first visualized in the graphic *This Corner of the World* (Figure 1). The form of the present workspace resulted from the attempt to extend into three dimensions the conceptual relationships that were being explored and discussed in terms of that two-dimensional graphic.

Both of these motivating sources shared in the intent to make relationships among concepts more visible, and thus more intelligible, through extending their display into a three-dimensional environment. In the first case, for display of codebook term relationships, the result could be conceived as a complex graphic that would allow more meaningful relations to be displayed than was possible through the alphabetical and simple tree hierarchical lists and networks available in the text coding software being used, AnSWR: Analysis Software for Word-Based Records (U.S. Centers for Disease Control, 2003). The multilevel concept network management software Axon was chosen for this purpose, after initially using the semantic network creation and management package SemNet (Semantic Research Inc., 2002). Whereas SemNet required explicit links among semantic conceptual objects, and was limited in the numbers of nodes and links that could be simultaneously displayed, Axon allows the clustering of concepts without requiring explicit links, and allows the entire array to be viewed in its entirety.

Through this application, the capabilities of Axon became familiar and were available for the second motivating application, creation of a space that would support the primary goals imagined to be part of an interactive learning environment within a digital library. The two streams merged when the undifferentiated, multilevel space of Axon was chosen as the medium within which to create a three-dimensional realization of the *This Corner of the World* graphic.

Many of the theoretical motivations underlying this space have been presented in the sections above devoted to question-centered information environments, the resonance metaphor for information, and the cognitive constructivist approach to understanding information processes. In broadest terms, the environment that results should allow the greatest amount of autonomy for the structuring of problems and meanings among all participants, while allowing transparency and the discovery of conceptual relationships across diverse participants and groups. In terms emerging from the New Directions project, the question became one of linking diverse sets of communities of users, all with different frames of reference, without requiring the establishment of a unified vocabulary, or common language, as prerequisite to the discourse. In terms of question-centered approaches to information and learning, the problem became one of how to bring questions and communities of questioners into proximity without assuming that any of the participating members of these communities has privileged knowledge which it then becomes the task of others to access or otherwise obtain. Abstracting questions from the knowledge of all participants is conceived as one way to level the field across communities of inquiry.

The structure that is offered here can be conceived as a single instance in a universe of many similar structures which are created and maintained autonomously by participants in a shared community of inquiry. These similar structures would not need to be crafted with the same figures and relationships as suggested here. Local workspaces could be structured to meet local needs. These local constructs could then be federated for particular purposes, such as the identification of common questions, through emerging standards such as the Topic Map standard (Biezunski, Bryan, & Newcomb, 1999). The strategy of federating workspaces is outlined below in the section on future work in Chapter 10.

Steps in Building the Workspace

This section provides a brief review of how the particular form of the workspace was crafted given the visual precedents, theoretical goals and available software described above. The graphic *This Corner of the World* suggests that questions, or the complex mix of knowledge and uncertainty that aims toward greater certainties or answers, involves processes that propagate from a stable originating space. This propagation was represented by wavelike forms intersecting across a surface that is limited by three curves that suggest the intersection of great circles on the surface of a sphere. Discussions around the graphic also included reference to standing waves as being symbolic of the places of particular meaning, or of gaps in meaning, that are experienced in discourse.

At the beginning, the candidate structure that was considered for expanding this image into three dimensions was the tetrahedron, which would result from multiplying the graphic image four times, and joining the multiples at the edges. A tetrahedron is the simplest 3-dimensional space, and its form begins to suggest a sphere or globe. Thus, a promising simple form for expressing the surfaces and intersections implied by the graphic would seem to be a tetrahedron.

Though a form such as the tetrahedron might be useful in spatializing the graphic, it was not clear how this might accommodate complex sets of conceptual relationships and allow these to be explored or made mutually visible in a coherent way. The result, three nested three-dimensional forms, is many steps removed from the tetrahedron (although eight tetrahedra are to be found in its central structure, the cuboctahedron; see the application example presented below in Chapter 9).

The steps involved in merging these concepts began with the recognition that the polyhedral subdivision of the earth's surface as found in the global map projections designed by R. Buckminster Fuller were visually similar to each face of the elementary

tetrahedron being crafted here. Fuller's approach also had the advantage of being an attempt to create a unified coordinate scheme that would include both geophysical and conceptual mapping, his "geometry of thinking," see Fuller (1975b) and Edmonson (1987, pp. 2-3). Exploring the many approaches to designing innovative architectural spaces led to the suggestion that the "tensegrity" structure, developed by Fuller in collaboration with sculptor Kenneth Snelson, might also afford a useful vehicle for charting paths or navigational exploration of the kind of space we were trying to define. The particular internal dynamics of the Archimedean solid cuboctahedron, namely the equal central vector lengths from its center to each vertex, suggested that this figure as a stable solid for our expanded visualization. Finally, the desire to include context as part of the structure led to the inclusion of an enveloping "context sphere" that has the form of an icosahedron.

These development steps went forward on several parallel tracks. One was the construction of physical models and exploratory drawings that served to provide background on the actual physical relationships among the various figures under consideration (Figures 5 and 6). The second was an experiment in creating the visualization of a polyhedral space within Axon. The structure, or set of consistent, nested, discontinuous figures, as it stands today is the result of these approaches taken together.

Concepts derived from the work of R. Buckminster Fuller have entered into the design of the workspace in several ways. First, a recognition that the wave propagation patterns in the graphic *This Corner of the World* (Figure 1) looked very similar to Fuller's approach to global geographic projection based on intersecting great circles and displayed in polyhedral nets reinforced the idea that both geographic and conceptual coordinate systems might be integrated into a single structure, and suggested a solution.

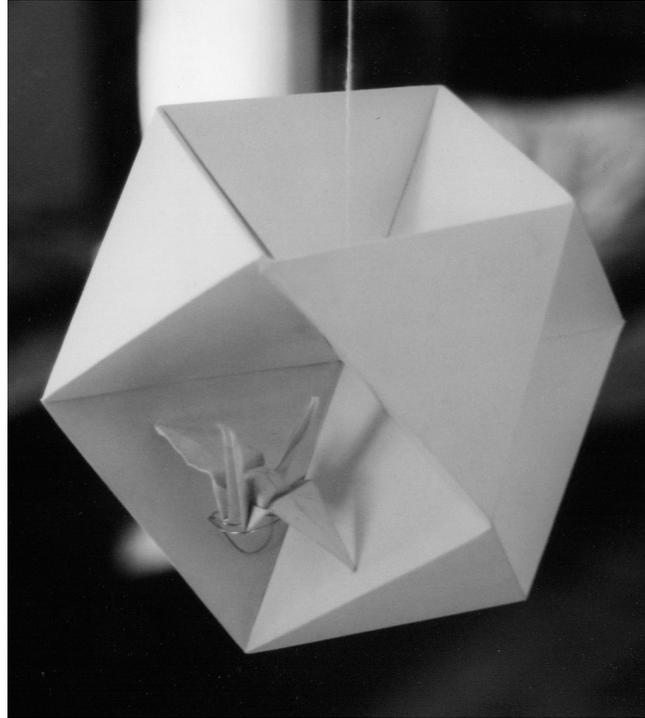


Figure 5. Octahemioctahedron, or octatetrahedron. One of the tetrahedra in this figure is used in the sample application described in Chapter 9.

Figure 6. Tensegrity model under construction.

Second, Fuller with sculptor Kenneth Snelson originally conceived of a structure that embodies the concept of “tensional integrity,” or tensegrity. A particular form of tensegrity, the expanded octahedron, was the first figure to be introduced into the workspace (Figure 7). Third, Fuller gave great attention to a particular Archimedean solid, the cuboctahedron (or truncated cube) which he gave the trademarked name Dymaxion when applied to his own work. Due to the symmetries of this figure, including the existence of four great circle circumferential paths and the equal lengths of vectors from the center to the vertices and connecting vertices across the chords, the cuboctahedron has found a place within the workspace (Figure 8).

I have relied on the works of Edmondson (1987), Kenner (1973; 1976), Critchlow (1970), Loeb (1991) and Fuller himself (1975a; 1975b; 1979), among others, for explanations of Fuller’s work. I found that Fuller’s geometry not only would help solve the problems of expanding the graphic *This Corner*, but it also fit my sense of what might be needed to visualize the resonance metaphor of information in multidimensional space.

The particular structure that I found useful was the tensegrity icosahedron (more exactly an “expanded octahedron,” see Pugh, 1976, p. 11), in which three parallel pairs of compression struts are held in stable orthogonal three-dimensional relationship – without any of them touching the others. (Figure 7). This was seen as being a solution for the attempt to surround or intersect a tetrahedron with a pair of parallel trefoil knots. As it turns out, the resulting structure does not seem to provide any consistent relationship with a tetrahedron – at least, this is not preserved in the figure within the workspace. The important point here is that the sort of figure that is expressed by the *This Corner* graphic can also be expressed, in physical 3D, by the tensegrity expanded octahedron, which provides a stable structure that is composed of forces in balance (“Tensegrity describes a

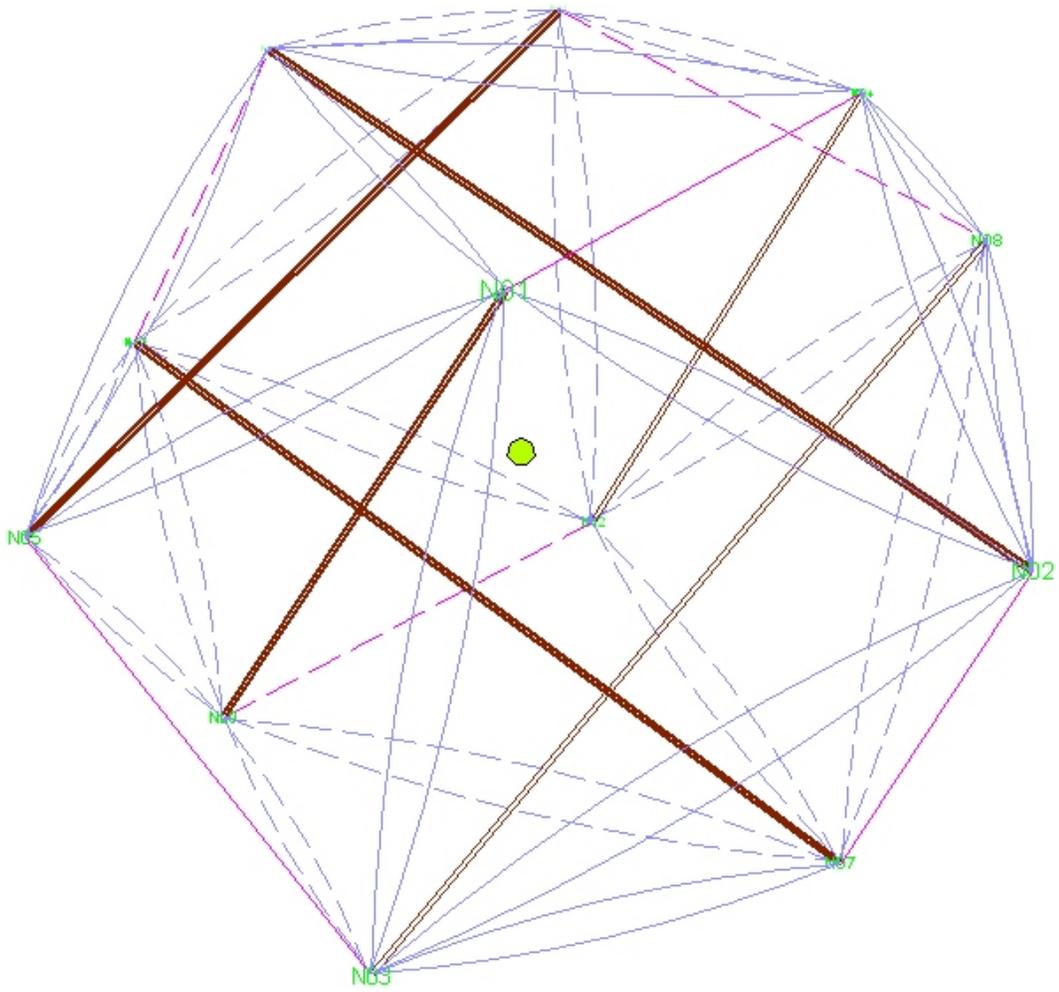


Figure 7. Expanded octahedral tensegrity. Tension elements are represented by thin curved lines; the straight members are three pairs of compression struts.

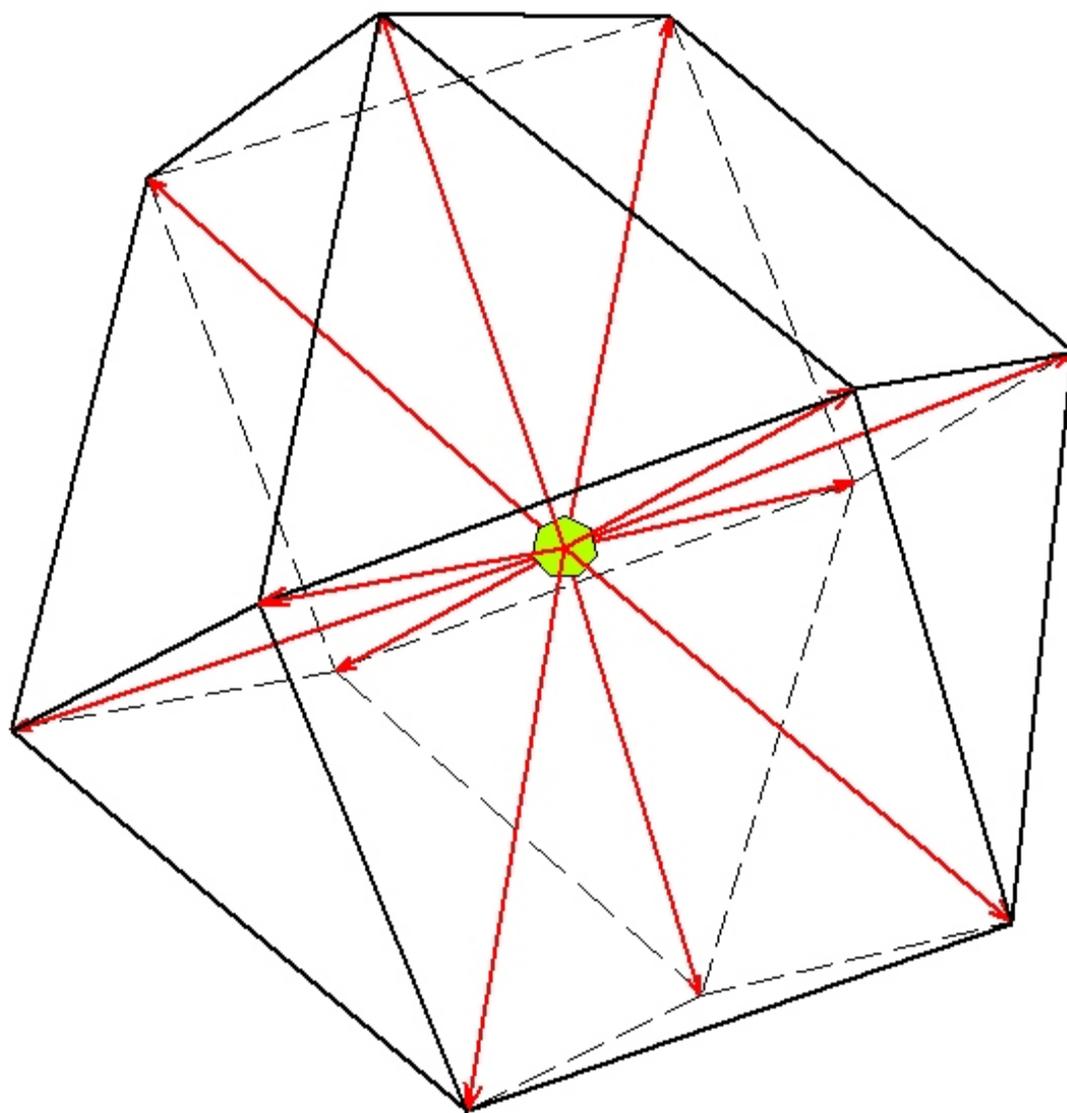


Figure 8. Cuboctahedron showing central angle vectors.

structural-relationship principle in which structural shape is guaranteed by the . . . continuous, tensional behaviors of the system and not by the discontinuous, exclusively local compressional member behaviors.” (Fuller as quoted by Edmondson 1987, p. 244).

The use of tensegrity as a form of nondirected graph seems similar in intent to an established graph layout called the “Spring Layout.” According to Herman, Melançon and Marshall (2000) this “stands for all nondeterministic layout techniques, also called *Force-Directed Methods*. They report that Eades was the first to propose this approach in graph drawing, modeling nodes and edges of a graph as physical bodies tied with springs. “Using Hooke’s law describing forces between bodies, he was able to produce layouts for (undirected) graphs” (p. 29). Further description of the spring layout may be found in a recent article that reviews spatialization methods for nongeographic information visualization (Skupin & Fabrikant, 2003, p. 103).

It should be noted here that the tensegrity figure in this workspace is only an image, and does not have the capacity to behave in the digital environment as a physical tensegrity would. The figure included here was created based on observation of an existing physical model. The great advantage of the physical tensegrity structures is that the relationships among the forces that determine the structure and the physical stability that results creates an immediate understanding of the whole system. Realizing these characteristics in the digital environment, rather than just representing them, is suggested as an objective of future work.

Elements and Affordances of the Heuristic Workspace

The workspace is composed of elements and features that are available in Axon, an off-the-shelf computer application. A brief description of Axon’s features precedes a description of the specific elements of the workspace. This will be followed by discussion of the affordances or apparent possibilities that this configuration suggests or

allows. The term affordances derives from Gibson's assertion that objects and conditions of the physical environment may be perceived directly in terms of their use values for the organisms that perceive them (Gibson, 1979/1986, p. 127 ff.).

Axon (Axon Research, 2003) provides three basic entities (objects, links and shapes) to which a large number of relationships and actions can be assigned. Axon provides a large 2D workspace (20,000 pixels square) arranged in a multilevel environment (500 available levels). Each level of the Axon workspace can be seen in a single view, and multiple levels can be viewed simultaneously. Axon's multilayer approach is reminiscent of coverage layers in a geographic information system. Zooming allows easy contraction or expansion of views. Axon's objects can contain text, or can be assigned actions such as opening external text, running programs, opening other Axon objects, following link pathways, etc. Objects can be connected by explicit links within and across levels, and operations such as computation and simulations can be programmed into object and link relationships. Other Axon features include: location of objects by name and contents by means of full text search; turning levels on and off, including specifying ranges of visibility for multiple levels; selection by color including hiding or visibility of all objects and links by color; manual and various automated choices for sequencing objects; full text output of the contents of objects by means of manual or automated sequencing. Every object in Axon has an x, y, z coordinate position, based on bitmapped pixels and the level at which the object is located. Different objects are allowed to have identical names, but all are distinguished by the automatic assignment of unique object identification numbers.

Though Axon provides a very robust and flexible environment, and comes packaged with dozens of templates for visual arrays and computation across networks of objects, its multilayered space is undifferentiated. First-time users are often inhibited by the unlimited possibilities of the space. Lacking internal structure, effective distribution

of Axon's capacities across its multiple levels is difficult to imagine. It was an experiment in creating an actual three-dimensional structure within Axon's undifferentiated multilevel space that led to the structure proposed here. This attempt was based within the intuition expressed by Herman, Melançon and Marshall that 3D "lends itself to the creation of real-world metaphors that could help in perceiving complex structures" (2000, p. 31). Until Axon's undifferentiated multilevel space could be subdivided in an understandable way, through using forms that have cognitive plausibility (in this case, with regular polyhedra) the potential for effective use of this 3D space can be only partially realized.

Moving on from the particular elements and features of Axon, the structured workspace as it stands now contains the following figures: a center point, along with representations of a cuboctahedron, a tensegrity icosahedron / expanded octahedron, and a regular icosahedron. The process of introducing these figures began with the direct translation from a physical model of an expanded octahedral tensegrity (for identification and illustration of this figure, see Pugh, 1976, p. 11) into Axon across 25 levels. This was accomplished over several days of close inspection of the actual relations between the tensegrity's compression struts and vertices, placing them in corresponding relationships within the Axon workspace. A center was established on Level 12, coordinate (0, 0) that also is the center for the two additional nested polyhedra that were introduced into the model. These were a "context sphere" (which actually is a regular icosahedron) and a cuboctahedron.

Other elements of the workspace include the following: vectors, from center to vertices, for all figures; compression struts, vertex endpoints, and tension links or polyhedral edges connecting them; landmarks such as center points on each level and facet markers; and differentiation among objects by means of choices of colors, sizes and fonts for text, graphic objects, etc., provided as part of the Axon toolbox.

The workspace intends to afford the coordination of small and large scale spaces, in physical/geographic and social/cognitive domains. All of the structures that make up the workspace in its present state are based on regular polyhedra, not on the sphere. Any of the figures that are in place, however, might be projected upon a sphere, and it is in this that they provide the basis for a unified coordinate system, a theme of this overall work.

When the new space was first conceived, before its eventual construction within the Axon environment, the question of how a basic tetrahedral space might be traversed or navigated was considered. An exploration was undertaken to find what sorts of figures might be available to help define paths that would consistently intersect with the vertices or edges of the figure, or that might penetrate it in a way that would allow systematic scanning of the space and its contents. Such a pathway might allow viewing from all perspectives but embodying some constraints against simply random pathways for viewing.

An attempt that was made to use a trefoil “torus knot” or similar interlacing figures pointed toward the difficulties in creating patterns of traverse, penetration or intersection that would be consistent with tetrahedral space. Drawings of various solutions seemed to point toward paradoxical behavior of the figures, such as figure-ground and front-to-back shifts in perspective depending on how the intersecting figures were arranged. While no direct solution to the problem of designing consistent “scanning orbits” was found, this exercise suggested the potential usefulness for tensegrity structures as part of the proposed space. The compression struts of tensegrities are discontinuous, held in stable relationship with each other by means of continuous tension elements. This relationship of continuity and discontinuity seemed a good potential match with the character of the resonance metaphor. It seemed to be a possible environment an environment for spatializing the concepts of the *This Corner of the*

World graphic that seemed unavailable through expansion into a tetrahedral form. Thus, the first figure of the workspace structure that was created was the tensegrity. The center, cuboctahedron and icosahedral “context sphere” were all added afterward. These figures will be described further below in the section on elements of the workspace.

Given this review of the situational contexts which motivated the creation of the heuristic workspace, the character of the general space of which it is a part, and its structural elements, details about the kinds of relationships that are reflected in its structure will now be given.

The workspace is intended to support the work of an individual, group or community when confronted with the need to structure complex problems. No particular standard structure to assist in problem solving should be assumed at the beginning. It is assumed that every problem situation is unique, and that the perspective of each person who shares in this problem situation will also be unique. A space for structuring problems should suggest and allow for many possible approaches, and should not depend on the approaches taken in other settings as being required or even as models for local inquiry and learning. Nevertheless, the skills and experiences of different communities whose concerns may intersect with each other may often be of great value, and should be made available as resources. Though primarily conceived as providing an environment for clarification and resolution of issues of immediate local concern, making these structured workspaces available for public inspection and exploration may increase the likelihood of learning and the emergence of creative solutions.

Toward ends such as these, the present workspace offers a number of features and structural relationships reflecting many of the commonly accepted ways of structuring conceptual relationships, as well as some that are more unorthodox. The following brief notes summarize what might be considered the affordances of the structures in this space:

- The workspace has “cognitive plausibility.” All of its elements can be constructed and demonstrated as physical models, and although the concept of tensegrity or even knowledge of polyhedra in general may not be common, the relationships among of such structures is easy to describe and understand.
- There is a center, a point of reference to which all the other figures of the structured space are mutually related. This may be used to represent the spatial concept of centrality in its many forms: as primary conceptual landmark, as point of highest certainty, as locus of accepted assumptions, or negatively, as the place of ultimate unknown, the nave about which the wheel of knowledge turns.
- Undefined as well as definable spaces are provided. All of the figures are transparent and consist only of nodes and links. While the figures in the structure provide many possibilities for defining and creating internal differentiation within the workspace, the entire region outside the context sphere is totally undefined, and definitions within the structure are the product of the workspace user.
- The importance of context is represented by means of a surrounding icosahedral “context sphere” which is structured to suggest that context is permeable, dynamic and interpenetrates the rest of the structure; see Figure 9. This structure reflects Mark Johnson’s discussion of Searle’s concept of a Background that permeates intentional meaning Networks. Johnson (1987, p. 188) states “if the Background really does *permeate* and *shade off into* the Network, then it must have a character, a structure, somewhat akin to structure in the Network. . . . Where we draw the line as we move along the continuum of structures will depend upon our purposes, values, and other assumptions. But no line of demarcation will exist ‘in the nature of things.’”

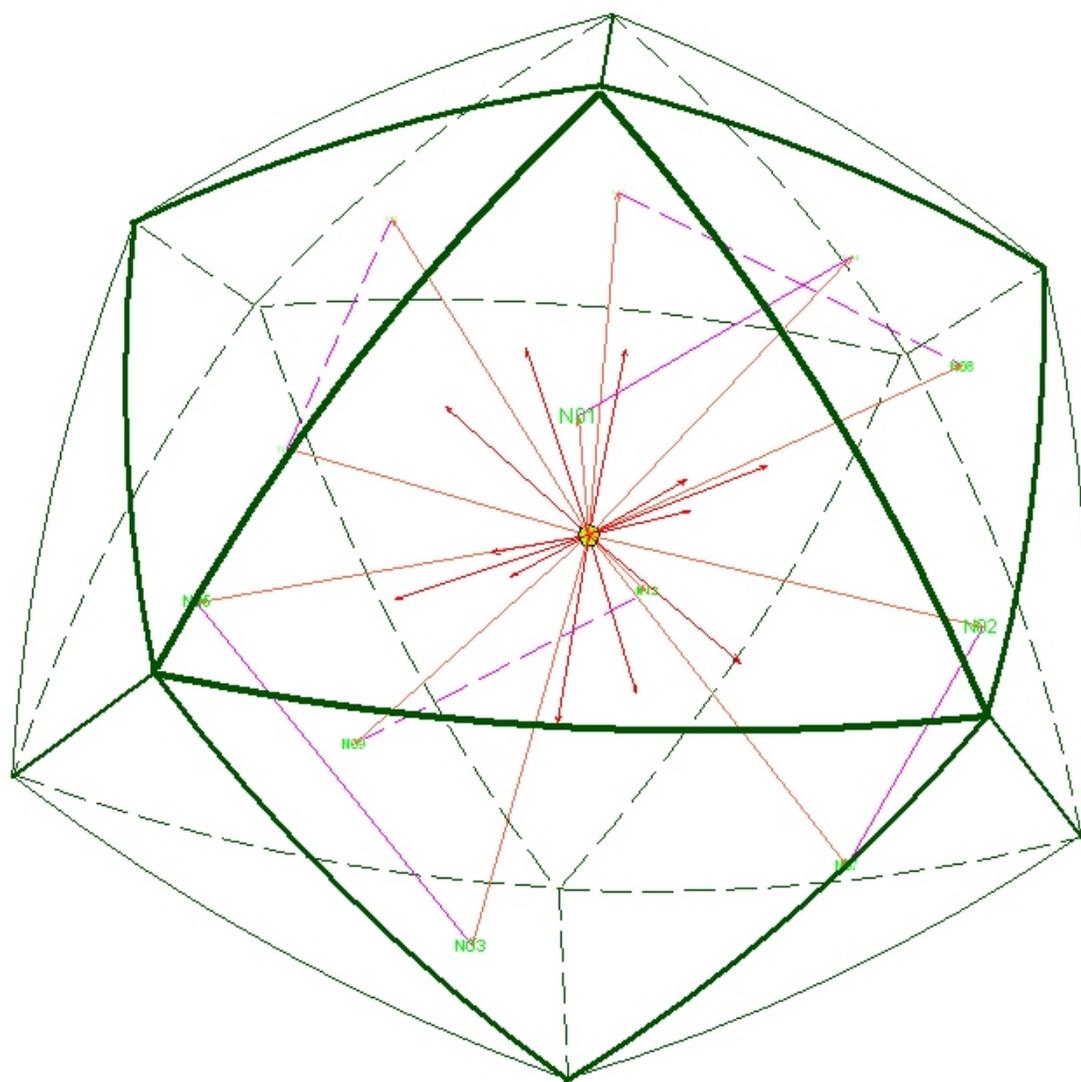


Figure 9. Icosahedral “context sphere.” This is shown with are the surrounding central angle vectors to vertices of cuboctahedron and tensegrity.

- The workspace as it is now structured suggests an arrangement for the display certainty and uncertainty relationships. The most well defined position in the structure is the center, located at coordinate (0, 0) on level 12. The most well defined figure is the closest to the center, the regular Archimedean solid cuboctahedron. The next figure away from the center, the tensegrity, is stable over time, while maintaining this stability through constant dynamic distribution of changing tensions across the tension elements. The context sphere, the farthest from the center, is intended to be minimally defining and maximally porous. Outside the context sphere the space is undifferentiated and undefined. Through this ordered progression, objects and concepts might be arrayed in terms of their relative uncertainty or definiteness.
- Multiple frames of reference can be displayed consistently in one view, without the need to have direct translation or transformation across frames. In the current example, three sets of three dimensions can be displayed simultaneously in this multidimensional workspace.
- Objects that populate this space can be displayed as single entities, or they can be formally linked as networks, arrayed in clusters suggesting fields, or arranged along vectors suggesting the directions of operation of forces within the space. The meanings of the symbolic objects that are managed in this space can be represented in several ways: explicitly, by embedding definitional text within the objects, or by assigning values to links across objects; or implicitly, through relational arrays, with significance of the array determined through analysis of the object clusters.
- Networks may be represented by the chords that connect the vertices of the polyhedra. A graph representing “small world” phenomena can be seen in the

tensegrity, with the tendons representing local “strong ties” and the cross-structure compression elements representing the long-distance “weak ties.”

- Manipulability and multiple location of objects / tokens makes this a space for sorting, a fundamental cognitive activity, and also a place for discovery of the emergence of formal and informal categories (prototypes, in Rosch’s sense) that are used in the sorting process; thus, a place for cognitive learning and discovery.
- Containment and inside / outside relationships can easily be represented here. The context sphere provides a structural boundary which suggests an inside and an outside to the space as a whole. Containment can be conceived as the confinement to a physical container, or as cohesion due to compressive forces. Such forces are found in the tendon elements of the tensegrity. Forces of expansion may be represented by vectors from the center outward to vertices of the figures.
- Structural dynamism can be inferred. Though the structure, composed of nested polyhedra and a tensegrity, are in fact static (though future software modification may allow transformations and rotations) there is a dynamism about the structure as a whole, that makes it into a “charged” space that can energize the work performed within it.
- Frequencies and periodicity are present in the physical tensegrity structures. Tension elements are always actively adjusting and redistributing changes in tension across the entire structure. The same elements in the tensegrity figure of the workspace can be used for the placement or representation of concepts that involve dynamic change and periodic events in time.
- Relationships implying opposition and bi-polarity can be represented. Polarity relationships are found in both physical and conceptual dimensions. These may be represented in many places throughout the structured space, including across opposing central angle vectors, across the length of the compression struts in the

tensegrity (three pairs of two struts are available, suggesting the opportunity to represent cyclically alternating opposing forces), and in the opposite-facing facets of the figures. Because the structure suggest an overall dynamic stability, the bipolar forces are also most likely to be represented as being in balance. However, any of the vectors, edges, struts or facets may be changed in length, width, numeric value, etc. allowing for the emergence of nonsymmetric structures that could represent imbalances in opposing forces.

- The structures allow groupings in several different numeric patterns. Patterns that occur in various multiples can be represented by parts of the structure. These include the numbers one (the center as single point of reference; as individual symbolic objects), two (bipolarity of compression struts, hemispheric symmetry), three in many forms (intersecting planes, three-dimensionality of each polyhedron); four (tetrahedra, available within the cuboctahedron; which figure also provides six square faces, the number of faces in a cube), eight (group of eight tetrahedra making up the cuboctahedron), 12 (vertices of the icosahedron, central angle vectors to vertices), 14 (facets of cuboctahedron), 20 (faces of icosahedron), 30 (edges of icosahedron) and so forth. Of particular potential usefulness is the availability of intersecting planes, either three planes intersecting orthogonally at 90 deg., or four planes intersecting at 60 deg. The orthogonal planes also can represent the Cartesian x, y, z coordinate system; see Figure 10.
- There is potential for simultaneous display of cognitive and geographical maps. These may be coordinated through rotation of the figures to match conceptual and locational relationships along central vectors. Although a consistent geography could not be introduced in the workspace as it stands as limited by Axon's current capabilities, the potential for creating this capacity based on the conceptual model of the workspace will be explored in future work.

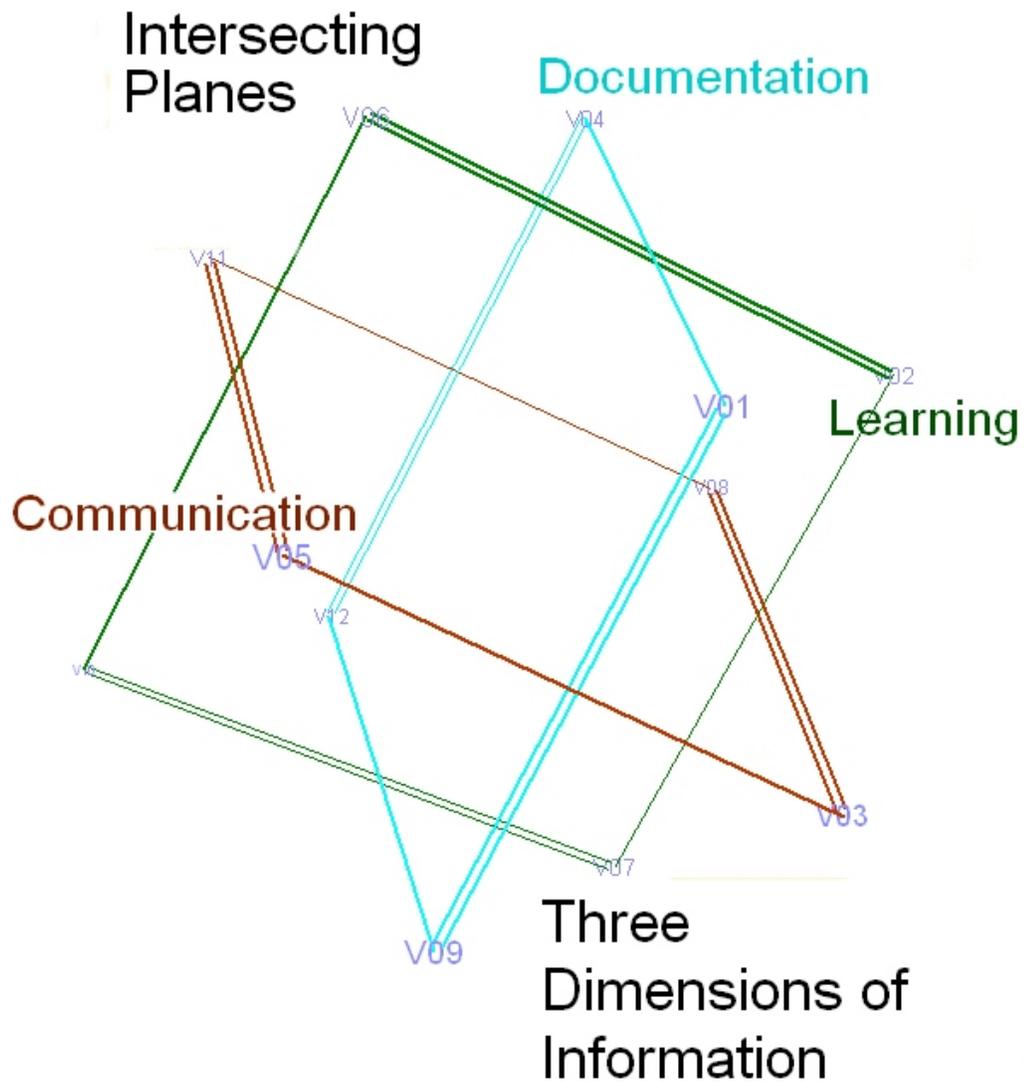


Figure 10. Three orthogonal intersecting planes. These are intrinsic to the cuboctahedron, and are used here to illustrate the Three Dimensions of Information.

- Because the figures are nested but non-intersecting, relationships that are characterized by discontinuity may be expressed. Just as clustered objects may indicate meaningful relationships even without the presence of explicitly defined links, the structure's figures are seen to be in relationship without requiring direct paths or correspondences to be present. Since each of the figures can be taken to represent a separate frame of reference, the present configuration allows three sets of three-dimensional frames to be viewed simultaneously, without requiring prior definition of terms across them. Discontinuity is also represented through the presence of compression struts in the tensegrity figure, which by definition represent discontinuous fields of compression distributed in continuous fields of tension.
- Given the representation of structural discontinuity, what keeps the discontinuous elements in stable relationship? One concept that applies to this is gravity. The concept of gravity is one way to account for stable proximity relationships when physical connections are not in place. In conceptual as well as physical structures gravity effects are understood to be present, if only metaphorically, as in the clustering of concepts around categorical prototypes. Within the workspace, the clustering of concepts without requiring explicit links, as well as the array of tension elements that are the contraction forces of the tensegrity figure can represent gravity relations.
- The user is in charge of the environment. This is essential for a truly 'subject centered' system. This affords an environment for different cognitive / learning styles, such as "holists" vs. "serialists" (Pask, 1975). In learning about cognitive aspects related to the creation of a space such as this, several writers cited motivations related to recognizing and supporting different learning styles; for example, Canter, Rivers and Storrs (1985, p. 101), "It is easy to imagine two

expert users with different characteristics, one methodical in his approach to work, the other more erratic and inspirational. While both might be successful in achieving their aims within a data-base / expert system, it is likely that they would be more effective if operating in a software environment that was more sympathetic to their individual styles.” For a general discussion of the relationships between “multiple intelligences” and learning processes, see Gardner (1983).

Many of the relationships suggested above as being the affordances of this workspace may overlap with each other in some measure. To some extent all are speculative at this point, and not all may be effectively realized by means of the Axon development environment available today. It would be helpful to attempt a consistent classification of the structural elements and the relationships they may best be used to display. The emergence of a well-ordered range of visualization approaches along these lines will be the result of future development of the workspace in actual application settings.

One of the most important features of the workspace is that it provides a place to put things, a place to gather the many factors of problems and concepts, a place to sort and arrange these according to local requirements. This gathering, placing and arranging is part of a general process of orientation that must be undertaken when any problem is being solved or similar process is underway. It was the purpose of the developers of Axon to provide such a space, which made it suitable as a choice for the environment within which the workspace could be built. What has been added here, by introducing the figures that make up the workspace, is the availability of a flexible set of graphical and structural elements that plausibly may be associated with a wide variety of conceptual and physical relationships. See Figure 11 for an example of the workspace as populated by conceptual objects.

Discussion and Summary of the Heuristic Workspace

An originating question that motivated this space asked, if an interactive learning environment were to be created as part of a digital library, in what sort of space would this activity take place? What might actually happen in this learning environment, and how might it be different from the sorts of spaces that are now conceived as models for collaborative online workspaces? The present approach attempts to avoid some of the major intractable problems of creating shared knowledge systems, such as the assumption that “common languages” across communities of inquiry are prerequisite to rather than being the consequence of interactions within and across the spaces.

The workspace is intended to fit well with the resonance metaphor for information, replacing the concept of transfer of information objects with dynamic, connotative, relational structures that may be brought into visible proximities. The workspace intends to accommodate the coordination of small and large scale spaces in both the physical/geographic and social/cognitive domains. As detailed in the bulleted paragraphs on affordances above, the spatial relations that can be expressed through relationships, regions and components of the workspace include: centrality; objects in context; bi-polarity; outward-expanding forces; containment and containing forces; network relationships; discontinuity; intersecting x, y, and z coordinates; intersecting planes; inside and outside; and event frequencies, among others.

The overall approach to information presented in this work is an action orientation, seeing information as manifesting in the continuous creative work of people, who are always generating information and informational contexts as part of their ongoing problem solving, sometime very informal and sometimes approaching formalization through the articulation of questions. This space puts primary importance of the person, or collaborative community, in the creation, definition, linkages within the space. It is meant to be one component in an integrated overall approach to encouraging

autonomy and diversity of work, in a dynamic structure with problem-solving built into it as a core idea. The space also serves the goal of providing a single coordinate system within which multiple frames of reference can be simultaneously realized and visualized. In this case, the workspace affords simultaneous potential of physical geographic and socialcognitive approach to mapping, presented in frames of reference that are discontinuous but whose relationships can be coordinated within a single view. This is a very different approach from the established geospatial base approach, which attaches non-spatial or non-geographic aspects to a geographic base, creating a hierarchy of frames rather than a coordination of frames as is intended here.

The space that is presented here is both familiar, in that it is based on regular geometric forms that people already understand, and unfamiliar, in that the configuration is not a natural system, and at least part of the structure (the tensegrity) is nearly unknown to the general public. This tension between familiarity and the need for discovery may be an asset of this structure, since part of the intent is to create a space where creative problem solving might occur, rather than a space in which established understandings are simply represented.

To this extent, the approach taken here does not fully share assumptions such as, “The objective in creating a geographic analogy is to generate an information landscape based on experiential properties of the real world” (Fabrikant & Battenfield, 2001, p. 265). This space is not map-like, in the sense presented by Skupin (2002) who notes the importance of meeting user expectations as related to issues involving map-like, geographically-based visualizations for abstract spaces. “Users expect map-like visualizations of non-geographic information to *function* like geographic maps, at basic and higher-levels. Any mismatch between this expectation and the reality of an interface should be of concern and at the very least be communicated to the user” (p. 166). In the geometrical approach taken here, user expectations would be expected to be fewer and

less critical, due to the unfamiliarity of the space. Though it is assumed that this will be made up for in the relative ease in interpreting the space as given, testing the reactions of users on first confronting the space would be expected to be helpful in future developments.

Physically viewing an object, and conversation among people while viewing an object (such as a map) together, is an important aspect of understanding even abstract concepts. This is cognitively related to what was discussed as “kinesthetic memory” or motor learning in the section on action orientation in Chapter 4 above. This kinesthetic mode, complementing verbal and imagistic, has not been adequately expressed in digital environments – perhaps one day to be reclaimed through true virtual reality. The object manipulations allowed by Axon also enhances this important hands-on requirement. Shared viewing and work based on shared objects is recognized by Hutchins (1995) as the necessary social aspect of all cognition. The social aspect of knowledge was particularly clear to him in his ethnographic study of navigational systems for ships, and their use by the people who navigate with them. That charts are visible in shared interpersonal space is an important part of these social cognitive systems. Our model of cognitive processes needs to include this public factor. “The model of human intelligence as abstract symbol manipulation and the substitution of a mechanized formal symbol-manipulation system for the brain result in the widespread notion in contemporary cognitive science that symbols are inside the head. . . . When the symbols were put inside, there was no need for eyes, ears, or hands. Those are for manipulating objects, and the symbols have ceased to be material and have become entirely abstract and ideational” (p. 365). The hands-on character of interaction with the workspace, as well as the possibility for groupwork around and across such spaces, reflects this perspective.

It is easy to conceive that separate workspaces could be built for different problem solving situations. To call this a “heuristic workspace” puts focus on the idea

that it is a place to work, not a place where work is somehow done by a machine for the worker. Emphasizing the concept of workspace also implies the contingent, tentative, work-in-progress nature of what may be found by anyone exploring such spaces.

One of the outstanding features of the workspace structure is the inclusion of multiple three-dimensional figures that are in a stable though not fixed and predetermined relationship with each other. This has been accomplished through nesting, with all three polyhedron-based figures centered on a common origin.

The importance of distinguishing spatial frames of reference from spatial vocabulary was discussed above in Chapter 3. The use of such frames of reference is required in order to properly contextualize all forms of expression, including expressions about space. The need to provide reference frames for any set of related concepts pointed toward the nested multidimensional set of structures that are present in this space. Just as frames are mutually untranslatable (“three distinct frames of reference are ‘untranslatable’ from one to the other, throwing further doubt on the idea of correlations and correspondences across sensory and conceptual representational levels,” Levinson, 1996, p. 152) so the nested polyhedra do not intersect and are not presumed to reflect common coordinates, except in terms of being defined by vectors emanating from a shared central origin. The strategy taken here is to bring multiple views / multiple frames into a single simultaneous view; rather than attempting to accomplish translation across the figures. Here, frames of reference are provided in a spatial context, without predetermining the values that might be assigned to places, regions or relationships in this space.

The nested polyhedra of this space can be viewed as approximations for spheres, and can be projected onto spheres. Anthony Judge (1980/1984) suggests that “spherically-oriented presentations” may lead to “greater comprehensibility and communicability” than flat tabular presentations of concept schemes. He posits a “link

between prime number factors and polyhedral spherical approximations. Nested concept sets may then be envisaged as ‘encoded’ by nested polyhedra or their topological features. The relationship between symmetrical forms and memorability has been explored.” Of more significance to him is the hypothesized transformation of concept sets via “‘transformation pathways’ between certain polyhedra thus maintaining structural continuity” (pp. 10-11 of 13). We recall the mnemonic approaches of Lull and Bruno, described above in the section of Chapter 4 devoted to the spatial organization of knowledge. The present work as a whole can be seen as a contemporary extension of the classical method of *loci*.

Given the organization of Axon into discrete layers, the creation of geometric spheres is not possible. Spheres are implicitly represented in the workspace as the bounding figures for the regular polyhedra. The subdivision of spherical surfaces by means of great circles is reflected here in the form of the edges (chords) of the cuboctahedron. The availability of hemispheres suggests the representation of complementary relationships, which bear some similarity to polarities mentioned above. Hemispheres are approximated in this space in the cuboctahedron, whose edges or chords can be projected onto great circles upon a sphere. Because the space can be entered from front to back (or from lower-numbered levels to higher) a viewing position can be attained that sees the space as if it were the inside of a concave hemisphere. This would be similar to the natural view people have of the world, with an approximate half sphere visible and another, “behind us,” not visible. Overall, the inability to construct spheres is compensated by the increased regular subdivisions of space afforded by the polyhedra, both on their surfaces and internally.

There are a number of features that are missing from the Axon-based workspace. Some of these are intrinsic to the available functions in Axon, and some are simply incompletely realized in the current state of the space. “Scanning orbits” or other

prescribed routes for traversal of the space have not been created. There is no 3D rotation, including the independent rotation of nested structures, a feature that would have to be available in a fully realized version. Definitions of dimensions are absent, such as the meaning of a token object's being in proximity to any particular vertex or facet. It is not yet possible to put weights on the various compression and tension elements – though this may possibly be accomplished by means of the simulation operations that are built into Axon.

Many elements of the solution offered here were “tripped over” in a way similar to the creative design process described by Storm as “eolithism” (1953). He presents three major approaches to the creation of structures: design methods, “tropismatic” activity and “eolithism.” Whereas “designers” must know what they want, and must specify their materials beforehand, the tropismatic nest building of birds is thoroughly constrained in terms of materials and outcomes but not particular choices and methods. The most open-ended and unexpected is the “eolithic” based on the metaphor of “stumbling upon” a rock or other available material, which then can be put to inventive use by the creative builder.

Overall, this space provides an approach that is responsive to the call presented by Anthony Judge in many writings, and in the *Yearbook of World Problems and Human Potential* coordinated by him, stating need to move toward “multipolarization.” There it is asserted that many problems are described in polar terms: inequality vs. equality etc. “This suggests the need for ‘conceptual’ devices to reconfigure the relationship between opposing positions, categories or paradigms into a more complex pattern of counteracting viewpoints. . . . Such patterns should be sufficiently complex to reflect appropriately the recognized multipolar relationships that are obscured by the powerful conceptual dynamics associated with a focus on polarization. In this way they contain variety rather than ignoring it. . . . Given the ambiguity of words in representing fundamentally

contrasting viewpoints, it is appropriate to use a non-verbal representation system to denote such alternatives and to indicate the nature of their relationship to each other” (Union of International Associations, 1986, Secs. TM, XTM).

Chapter 9

A SAMPLE APPLICATION ILLUSTRATED

The workspace described in the preceding chapter is intended to provide a robust, flexibly structured digital environment within which the relations between such entities as concepts, objects and places may be brought into meaningful visual arrangement. Because the structure as presented is only one of many possible similar approaches, and because the particular forms and relationships that are included will be unfamiliar to potential users, a simple application is suggested here that illustrates how this space might be used.

This example incorporates an existing narrative that was presented through use of graphics and figures of speech based structured in the form of a triangle and a tetrahedron. The essay in which those figures appeared, “GIS Without Computers: Building Geographic Information Science from the Ground Up” by Helen Couclelis (1997), aimed at creating for its readers an image of the conceptual relationships that exist in the discipline of geography, and then to relate these to a recent addition to the realm of geography, the geographical information sciences.

Couclelis’ essay presents these concepts in a traditional form, narrative text with two-dimensional illustrations. The illustrations are not reproduced here, but the structures used in them will be described. In her essay, four graphic illustrations are presented, representing a deconstruction of the concept of GIS, a “geographic triangle,” “the ‘other’ geographic triangle,” and the “GIS tetrahedron.” The first is a web that seems to be directed toward, or emanating from (more likely, given the aim of illustrating the process of “deconstructing”). The second, “geographic triangle,” is a standard downward-pointing triangle with the three angles or nodes labeled “empirical,” “experiential,” and “formal” with the sides or edges labeled “geographic concepts,” “geometry & topology,”

and “geographic measurements.” The general impression given by this graphic is that there are three basic orientations toward the discipline of geography, and particular classes of geographic practice link or occupy an intersection across pairs of these orientations. The simplicity of the figure suggests that the concepts it represents could also be given in the form of a Venn diagram.

Couclelis provides interpretation for the graphics in the body of her text. In the text, the key words in the graphics are highlighted by means of italics. This directs the reader’s attention to the places in the text where key concepts are discussed, and makes for easy cross-referencing between the text and the illustrations. Without the illustrations, the complex sets of relationships among the orientations and practices of geographers and geographic information scientists would be nearly impossible for the reader to grasp.

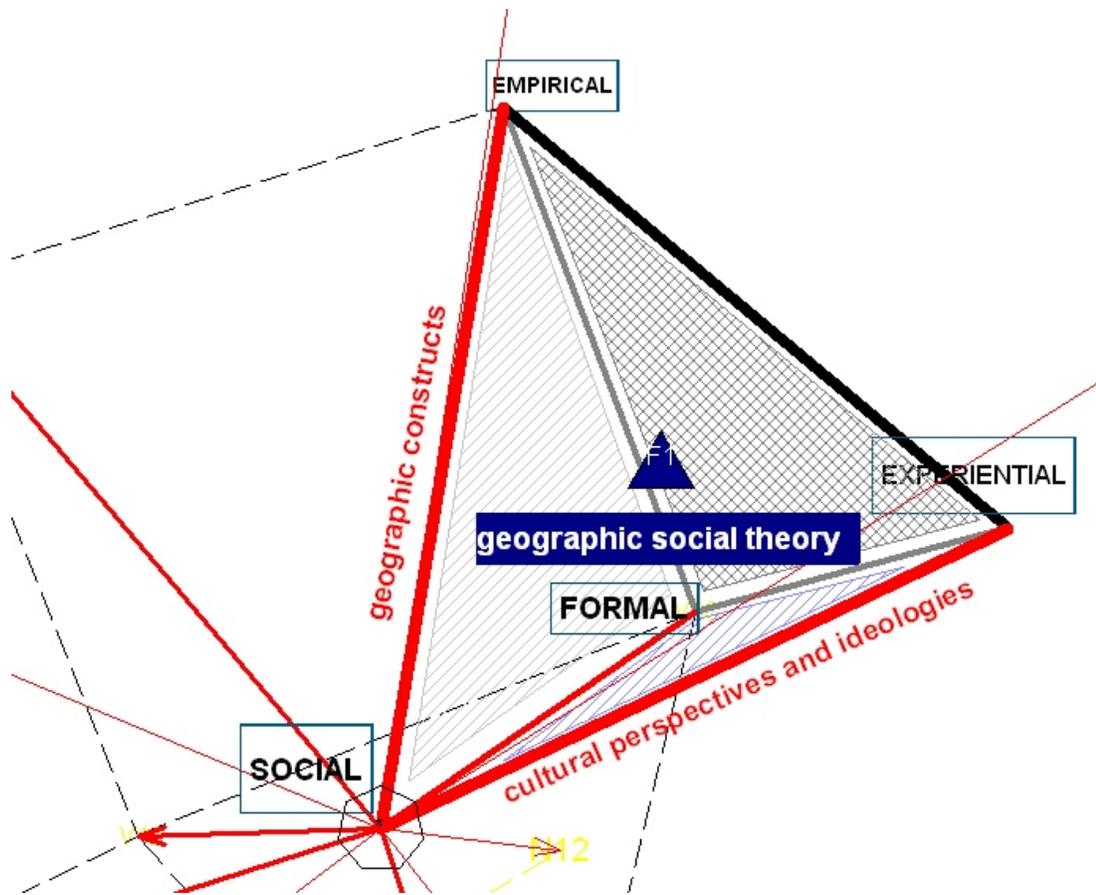
The next two illustrations presented by Couclelis show a progressive transformation of concepts from the realm of geography to the geographic information sciences. While the first two are well suited to two-dimensional display, the next two move into a three-dimensional realm. The triangle represented three orientations to geography by means of a two dimensional figure. In adding a fourth conceptual dimension, named the “social,” the sorts of relationships that could be displayed in an orderly way via labels on nodes and links became more complex. Couclelis chose a tetrahedron, the simplest regular polyhedron, for this representation.

This choice presented problems for display on the two-dimensional page. The edges and faces of the tetrahedron are represented by the addition of a dashed line, for the edge “hidden” at the back of the figure, and by shading the faces. In addition, the methods that link the orientations are not given in the figure at all. The reader needs to rely upon the text for the substance of her argument, and the text has become quite complex, given the multidimensional conceptual relations she is presenting.

Nevertheless, those relationships can be represented by a figure as simple as a tetrahedron.

At this point some advantages may be gained if it were possible to adopt a three-dimensional space for representing these relations, rather than a two-dimensional projection of a three-dimensional figure. In the present example, the figures provided by Couclelis have been reconstructed within the heuristic workspace. Two illustrations of the resulting figure are given here: the first is a closeup of the “GIScience Tetrahedron” as presented in Couclelis’ terms, and the second zooms out from the first view and shows where this is situated within the entire structure of the workspace. See Figures 12 and 13.

It is not being suggested that the conceptual relations that are shown in this two-dimensional representation of yet another three-dimensional construct should replace the originals in an essay such as Couclelis’. Rather, these relationships can be explored within the digital workspace itself. In that space, conveniently, the tetrahedral form is already available. The central polyhedron of this workspace is a cuboctahedron, which includes eight regular tetrahedra in its internal structure, all meeting at the central vertex and joined to each other at their edges. A physical model of this figure, showing available tetrahedra, is shown in Figure 5. These tetrahedra do not fill the space of the cuboctahedron; the spaces between the eight tetrahedra of the figure are occupied by pyramids, whose square faces are six of the facets of this polygon; the other eight facets are the outward facing triangles of the tetrahedra. Because the cuboctahedron has an important characteristic regarding its central and edge vectors, namely that the vectors from the center to each vertex, and the vectors connecting all of the vertices around the polyhedron, all are the same length. For this reason of this we are assured that the figure chosen for the translation of Couclelis’ image is in fact a tetrahedron.



SOCIAL

"The social vertex that completes the GISc tetrahedron adds three new sides and three new faces to the original geographic triangle. Let us examine them in turn. Connecting the social and the empirical are the simple and complex geographic constructs that society imposes on the world. These include the formal and informal boundaries of various sorts, the counties and the census tracts, but also the hierarchies of 'good' and 'bad' regions and neighbourhoods, the classifications of place into ordinary and special, protected and not, sacred and profane, yours and mine, public and private. Connecting the social and the experiential, on the other hand, are the diverse cultural perspectives and ideologies that distinguish one group's (and time's) tacit view of the geographic world from that of another. The entire social-empirical-experiential face is the realm of geographic social theory, a counterpart to the formal-empirical-experiential face better compatible with geographic science." (p. 223)

Figure 12. GIScience Tetrahedron. Hypertext embedded in the entity

“Social” as found in Couclelis’ text is expanded.

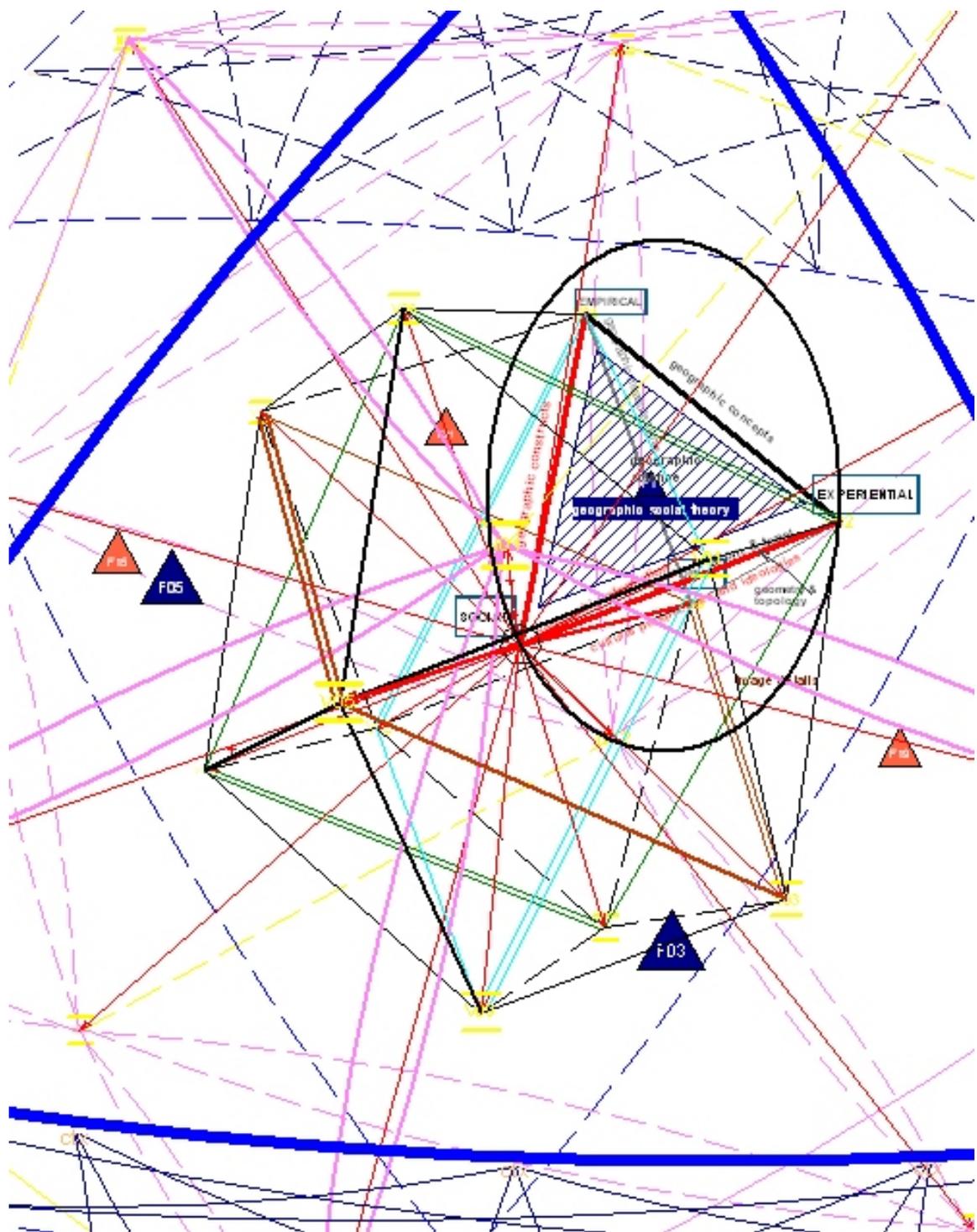


Figure 13. GIScience Tetrahedron showing other workspace figures.

As restructured in the workspace, all of the vertices and all of their connecting edges have been labeled according to the discussion provided in Couclelis' essay. In addition, relying on capabilities built into Axon, the workspace allows the embedding of hypertext within any object, or symbolic token, that is included in the figure. In the first illustration provided here, the node "social" has been expanded, showing part of the text provided in the text of Couclelis' essay. More or less text, or the entire text parceled out to the object tokens, could be included. In this way, a reader would have the ability to explore the text in terms of the exact spatial relationships that were assigned by Couclelis, without leaving the workspace.

Of course, this form of presentation is a significant departure from the standard illustrated text. Nevertheless, for purposes of adequately representing distinctions as well as commonalities among many concepts, moving into a multidimensional digital space for explanation and understanding (our intended "interactive learning environment") this approach provides possibilities.

It is also apparent that the tetrahedron we have used only occupies a small portion of the available structural relationships in the workspace. There is no need to populate the entire space, in any case. The space affords a rich variety of relationships, of which the single tetrahedron is one (and a convenient one, in this case). It would be easy to visualize a more populated space, for instance by illustrating relationships from other disciplines using the other tetrahedra, for easy conceptual contrast with the description provided by Couclelis for GIScience. Other narratives from other authors could also be collected, who might explain the conceptual relations of GIScience differently from the way Couclelis has chosen – these may not occupy tetrahedra; they may have been conceived in terms of tensions among various practitioners, and so would perhaps be arrayed across the tensegrity. Since many tensional elements are represented, a setting for a more complex description of the discipline is available than is needed for illustrating

Couclelis' work. If an alternative description of the discipline were made in terms of intersecting planes, each plane featuring an important dimension of the conceptual structure of the narrative, this could be accommodated through the available planes internal to the same cuboctahedron from which the tetrahedron was extracted. See Figure 10 for an illustration of the three intersecting planes.

It should now be clear that an additional advantage of this structure is that multiple different structural relationships can be accommodated without conflict within a single view. This essentially is the ability to include multiple frames of reference simultaneously, without requiring exact transformational procedures to link them. Since the space includes three three-dimensional structures that are discontinuous from each other, at least three simultaneous frames of reference can be portrayed. The actual number is much higher. Recall that the example in the paragraph above uses tetrahedra and intersecting planes, used totally independently of each other, that are both found within the cuboctahedron's internal structure. Similarly, the many affordances outlined in the previous chapter could simultaneously be put to work within one workspace.

In addition, though the essay being used here as an example essentially portrays the geometry of a discipline, there is no reason why the geography of the discipline, or particular elements of it (such as the locations of home institutions of practitioners who represent the orientations given in the conceptual overview) could not be represented, also. The surrounding icosahedron, called "context sphere" in the present workspace, could be used for a global geographic projection, on which such points could be located. These then could, if desired, be lined up along central vectors with the orientations named, though only one at a time. Simultaneous rotation of figures such as those described here could bring multidimensional physical, social and conceptual factors into comprehensible simultaneous relationships that could be interpreted with little difficulty.

These multiple relationships have the potential for the user, or explorer, to create new information or connections, or to observe inconsistencies, much in the way that geographic information systems allow discovery of new spatial relationships. In reconstructing the “GISc tetrahedron” into this workspace, based on the original text, several potential terminological and relational inconsistencies were observed, though not enough time was spent to assert that there were inconsistencies in the text narrative. What is asserted is that a space organized in this way is very robust in terms of the many sorts of relations that can be simultaneously displayed, and also provides potential analytic capabilities that could be called informal graphic logic.

That Couclelis conceived of the figure she presented as being a model for a more expansive structure of representations was explicitly stated. “The finiteness suggested by the geometric analogy is of course misleading, since any small region may be explored in arbitrarily fine detail: imagine a fractal polyhedron!” (Couclelis, 1997, p. 224).

Her choice of tetrahedron may have been somewhat arbitrary, and her purposes served by another figure, but there is an elementary logic to the choice. She is presenting GIScience as a system, and R. Buckminster Fuller, who asserted that all systems can be represented by polyhedra, observed that the tetrahedron represents the minimum system. Anthony Judge (1978, p. 5 of 22) quotes and comments on Fuller in the following terms, in describing an “operational space” he was considering: “The space is first conceived as distinct from its external environment. Fuller states, ‘A system is the first subdivision of Universe. . . . Oneness, twoness, and threeness cannot constitute a system. . . . Systems are unpredicted by oneness, twoness or threeness.’ Namely it takes a minimum of four vertices to define a set of planes giving insiderness and outsiderness, the basic requirement to ensure that a system is distinguished from its environment.”

Again, we should remember that the particular form as well as the particular conceptual relationships chosen by Couclelis to illustrate her text are hers alone. That

does not prevent us in any way from bringing them into juxtaposition with other conceptual schemes, even of the most contradictory variety, within one working space. To create a way to simultaneously view and relate of multiple autonomous systems of relationships, allowing for a system of systems, all brought into relationship even when they are discrete and discontinuous, is one of the main objectives motivating the creation of this workspace. The next step is to imagine multiple instances of such space, all created for different purposes but sharing commonalities in some measure, that can themselves be brought into juxtaposition. This then would become the “polycentric” design that is our goal. It is hoped that this simple sample implementation has indicated the potentials available within this approach.

Chapter 10

CONCLUSIONS AND FUTURE WORK

Summary

This work originated with an interest in access to public information resources and in the sharing of information, particularly geospatial data, across communities of interest and geographic communities. In particular, it was of interest to learn about how concepts of space and spatial relationships might be involved in information sharing processes. An outline of the background stages of this work is presented in the Introduction.

The unique character of each information situation within which issues of access could be framed led to the conclusion that the use of a geographic metaphor for visualizing information access would not be an adequate approach, except in the most schematic of terms. Many questions arose surrounding the theoretical frame from which issues of information access were being addressed. These included the perception that many of the terms being used, from information to access to sharing, were not well suited to the processes at hand. For instance, if a “transfer” metaphor for information is questioned, then the meanings of such terms as “sharing” and “exchange” need to be critically evaluated. The first part of this paper reports on many of the results of this evaluation. The result has been a ground-up rethinking of access issues based on an expanded, more complete and realistic idea of information than is now embedded in prevailing approaches, concepts and metaphors.

The outcomes of this process include the products, both tangible and conceptual, that have been described in the second part of this paper. These include the concept of a question-centered learning environment, the resonance metaphor for information, and the multidimensional heuristic workspace. All of these address a perceived inadequacy of the

prevailing metaphors and concepts of information, described here in terms of the transmission concept and conduit metaphor for communication, the information as object or resource concept, and the pathways-to-knowledge metaphor. These do not provide room for a person-centered view of information that sees information processes beginning and ending with the cognizant human subject.

The overall goal of the system design process has been to find solutions that will preserve the autonomy of individuals and communities at local levels, where control should be situated regarding the terms, categories, frames of reference, values and questions of relevance. The space suggested here is an innovation created within an off-the-shelf commercial software, the Axon Idea Processor. The workspace is an autonomous, stand-alone environment that affords the possibility of being federated with similar spaces through use of emerging facilities such the ISO Topic Maps standard (Biezunski et al., 1999).

This local autonomy should ideally be structured so that the values expressed will be available for the exploration and interpretation of others. A particular motivating question here has been how people who share in questions may be brought into closer proximity with each other through a shared working digital environment. The result offered here ultimately implies the creation of a federated constellation of autonomous workspaces that would seem to be structured more in the form of galaxies and clusters than in terms of a well defined network. A gravitational approach would seem to be an appropriate concept in terms of the forces that may bring related clusters into proximity. What seemed to be needed, and is attempted here, is a robust structure that allows many different sorts of relationships, yet constrains them in such a way that observers might begin to correctly interpret those relationships on their own terms.

A candidate for structuring the question spaces that would be part of the question-centered learning environment is the tensegrity. The tensegrity, as a stable structure

balancing forces of tension and compression, provides a useful spatial frame for questions. Questions embody uncertainties that could be represented by tension elements, while the vast knowledge that accompanies every question, usually implicitly, can be represented by the compression struts of the tensegrity. Questions have origins, motivating contexts and central goals, all of which can be represented by the set of figures that make up the heuristic workspace. In this way, the workspace is offered as a candidate for the spatial structuring of question spaces.

A significant aspect of the present approach, autonomous workspaces in which information relationships are grounded in a resonance metaphor, is the existence of a center that is integral to the space. The other prevailing metaphors for information processes, conduits and pathways, do not carry any implication of centeredness, or groundedness. Instead there is the intimation of infinite networks across which any sort of movement might be possible, where the choices are many and the results are often unpredictable. The existence of centers within the constructs that are offered here afford possibilities for stability and orientation that are not available in the alternative approaches.

The other spatial aspect which differentiates the present approach from the dominant metaphors is the character of movement within it. Whereas both the conduit and pathways metaphors imply movement of objects or persons across information terrains and through networks, the movement implied in the resonant environment is one of propagating wave forms, and locations are defined by the interactions among simultaneous waves expanding from multiple sources. These sources are another kind of center available in the imagery offered here.

The importance of frames of reference, especially spatial frames of reference as expressed in language, has become increasingly apparent during the course of this work. Whereas the attempt to ground the study in an empirical approach rested on the analysis

of spatial vocabulary, the terms of that vocabulary depend on reference frames for their meanings. Identification of frames of reference must accompany the interpretation of particular expressions.

Taken together, these design aspects, including the overall pluralistic goals, are what is meant by “polycentric” in the title of this work. Rather than seeking to replace the existing concepts and metaphors for information processes, the results offered here provide a third, complementary aspect. Taken together, we now can conceive of information as having three primary dimensions: communication, documentation and learning.

Many other advances were made conceptually during the progress of this work. In most cases these have not achieved a well defined form, and can be considered to be intuitions, working hypotheses or conceptual landmarks that will be useful in guiding future work. These include a growing understanding that one of the most important distinctions to be made in information environments is that of in-groups and out-groups, issues of social inclusion and exclusion generally. The consequence of this understanding has been to reframe issues of access in terms of transparency and visibility.

Very informally, awareness of “threeness” has grown during this work. People, at least modern urbanized English-speakers, like to present conceptual relations in terms of threes. Playing off of George Miller’s “magical number seven plus or minus two” (Miller, 1956), I have begun thinking of dimensionality in terms of “the magical number three plus or minus one.” A collection of concepts grouped in three has been started, quickly numbering in the dozens. The proposed three facets of information offered here, communication, documentation and learning, is an example; see Figure 10. Others include Cassirer’s three models of understanding, the affective / emotive, the intuitive and the conceptual (Entrikin, 1977); Levinson’s three spatial frames of reference, the intrinsic, relative and absolute (Levinson, 1996); and my own suggestion of adding a

third coding approach, the kinesthetic, to Paivio's theory of dual coding by means of visual and verbal processes (Paivio, 1979). Spatial structuring of concept relations must accommodate groupings of three in many forms, and the heuristic workspace does this.

It has become apparent that when representing social networks, people should be considered to be both links and nodes in the network. No links among people or ideas exist independently of the people doing the linking. People are responsible for the particular associations that compose their environments of meaning, and information systems or learning environments should allow maximum ability for people to create and maintain their own links.

This work also has implied an alternative approach to learning. Learning is the word that has been chosen to characterize a complementary but integral facet of the information concept. Our approaches to learning will vary depending on the metaphors we have chosen. Is learning largely conceived as a building-up of structure from pieces? Or is it more a matter of finding correspondences and convergences among many sometimes surprising elements, and then making efforts to strengthen the perceived linkages? In terms of the structures offered here, there is a shift in the concept of learning that is similar to the one that Fuller made when substituting the tensegrity form for the common form of building structure.

Discussion

This work supports the emergence of a new approach to information processes based on a resonance metaphor for information. In addition, a novel multidimensional space for organizing and displaying relationships among concepts, places and other entities. These originated in the search for resolution of a set of problems related to the more established alternative views about information generally, and about how spatial concepts might influence our thinking about information processes. Overall, this work

attempts to conceive alternatives to “information transfer systems” by situating the production of information in human, cognizing subjects. A significant portion of this work, including most of Part One and many references in Part Two, presents relevant research that points toward or strengthens the human-centered approach to information processes that is being advanced here.

The text of Chapter 8, describing the digital workspace, suggests one solution by which these alternative views might be implemented in practice. A digital space has been crafted that could be called a “multidimensional heuristic workspace” (a functional name) or “Ptolemaic nested polyhedral space” (if viewed structurally in terms that may begin to evoke familiar images).

Details about the research background and related project contexts for this work are provided in the Introduction. In particular, the resonance metaphor and the heuristic workspace were conceived within conversations among participants in New Directions Downeast. These are rooted in the quest for an actual space where an “interactive learning environment” might be realized as part of the overall concept of a digital library. As such, this space is aimed toward interactions among the users or participants in the library, rather than toward management or access to the data and documents that are part of its collections. Many discussions centered on the need to bridge different communities and values within such a system through building shared ontologies or “common languages.” The present design in many ways is an attempt to shortcut such immense and intractable problems by abstracting the positions both of system “users” and information “providers” through the creation of shared “question spaces.” Though some bridges or binding points would be needed in order to connect such spaces or allow them to be mutually visible, the requirement for extensive sharing of assumptions or vocabularies as a prerequisite for participation might be mitigated through implementation of this approach. Rather than needing to be established as prerequisites to discourse across

communities of questioners, the development of shared perspectives would be expected to result from the negotiation of uncertainties and meanings that could take place in such an environment of federated, partially autonomous, spaces.

The present work intends to illustrate the importance the use of appropriate metaphors might have for problem setting, as required before problem solving can take place. This perspective is explained by Schön in his essay on generative metaphors (1979) and finds support in works such as those of Benking and Judge (1994) and Kuhn (1993). It was largely through an attempt to imagine alternative metaphors that could assist in the design of an “interactive learning environment” that the usefulness of the resonance metaphor for information processes became clear. Once the resonance concept emerged, many instances were encountered in the literature of memory, communication and information. The nested polyhedra of the heuristic workspace are a direct expansion into three dimensions of a basic graphic that attempted to portray the forces that would be involved in such a “resonance metaphor” for information.

The innovations suggested here often involved a reframing of concepts already in general use, similar to the figure-ground reversals that capture our attention in Gestalt demonstrations of visual perception. The foremost of these was the shift from a data / resource centered view of information to one centered on the cognizant human subject. Attention was also given to frames of reference, including contexts, motivations and intentions, over and above the identification and definition of discrete information objects. For instance, this was found in the shift of focus from spatial vocabulary to spatial frames of reference. The concept of “information sharing,” firmly grounded in an object and resource concept of information, was set aside, with new emphasis given to visibility and transparency as goals of system design. Similarly, there is a growing sense based in this work that the concept of access to information could productively be replaced by one that emphasizes inclusion, shifting focus from physical barriers and

technical solutions toward understanding the important role played by social inclusion and exclusion, and the importance of in-groups and out-groups in understanding information sharing processes.

More fundamentally, during this work distinctions between the cognitive and the social are realized to be less clear than is often imagined. Similarly, maintaining clear distinctions between the social-cognitive and the geo-physical realms seems to be increasingly difficult. This leads us toward the search for solutions that presume we live in a unified world, a single field that is person-centered, and is simultaneously material and symbolic, cognitive and social, physical and mental. Legitimate distinctions still may be made among these facets. The present position simply asserts that we live within a single field within which many dimensions may be defined. The model of nested polyhedra offered in the structure of the workspace is a step toward allowing such coordinated, discontinuous, multidimensional frames to be viewed within one view, toward allowing a more unified view of our existence and the problems it involves.

Finally, the need to create inclusive, participatory environments for the mapping of information environments of all sorts was made clear at many points during this research process. In terms of social outcomes and policy intent, the overall goals of this work may now be expressed as: preserve autonomy, increase transparency.

In addition to topics that have been given more extensive and explicit treatment in the body of the text above, several themes should be mentioned that have been touched upon in various contexts throughout, including:

- *The concept of “gestalt.”* The importance and relevance of the work of Gestalt psychologists became clear through many of the readings that were consulted in preparation of this work. The concept of *gestalt* appears in the work of Lakoff and Johnson, whose approach to metaphor has been relied on here. For instance, in a chapter on “The Coherent Structuring of Experience” (1980, p. 77 ff.) they speak

of "experiential gestalts and the dimensions of experience." The idea of *gestalt* generally refers to perceptions understood as wholes rather than as sums of their parts, for instance in discrete sensations. In the present paper, the use of terms such as figure-ground inversion, the need to choose among frames of reference as part of interpreting symbolic expressions, and the realization that we live in an underdetermined world from which our understandings are always composed by means of strategic inference all are related to the approach taken by the Gestalt psychologists.

- *Indirect approaches, crooked paths and discontinuities.* Participation in many group discussions and observation of groups engaged in collaborative work made it clear that the most direct distance between two points, at least in the social world, is often a crooked line. One of the fundamental distinctions that people make in evaluating the usefulness of information offered by others is whether those others are part of in-groups or out-groups, and the many obstructions, blockages and social distances that are thus put in place are among the most difficult challenges for information sharing systems. Social distances are seen as positive values, and distances among groups in traditional societies cannot be attributed to geographical barriers only (Picken, 1975, p. 609) The value of the "small world" phenomenon is that it in many ways overcomes the insularity of local in-group clustering through identification of global weak links. Discontinuity is intrinsic to the constructivist view, and is explicitly given as a basis for Dervin's "sense-making" method. Effective information system design should make the most of these sorts of phenomena. Elements within a discontinuous universe are held in relationship through various forces that can be conceived as being akin to gravity. Accommodating the representation of such

forces, and eventually modeling them, is intended through the heuristic workspace as based on the resonance metaphor.

- *The importance of context.* All symbolic expression is situated and contextual. It is a significant shortcoming of many information systems, from broadcasting to the Worldwide Web, that context is not transported as effectively as are data. The part of a message that might only be located in such missing contexts is termed “exformation” by Nørretranders (1991/1998), who emphasizes that messages with the most depth usually include significant effort directed toward composing context as well as message. The use of metadata is one approach toward providing context to information resources. In contrast, the creation of relational spaces such as the heuristic workspace is an attempt to keep information elements or objects, here called symbolic tokens, situated within local contexts that do not require the universalizing standards underlie the metadata approach. Although a figure called a “context sphere” is available in the workspace, the context should be considered as interpenetrating the symbolic space, within which meaning is contextualized through local relations. These relations may be expressed through local clustering or through assignment to structures in terms of planes, bipolarity, centrality, and so forth. In any case, the importance of context has never been far from this discussion.
- *Information processes are closely related to making choices.* The phrase “information processes” is frequently used in this text, rather than use of the word information on its own, as an attempt to emphasize the action orientation of the information concept, and a way to step back from metaphors that focus on the object nature of information. The actions that are involved are generally related to making choices. First of all, choices are always made in deciding what information to accept, and what to reject, in terms of any particular information

situation. Why is “information” important to us at all? The ability to participate in information processes helps us to resolve uncertainties, helping us to make choices based on an informed interpretation of our world.

- *Creativity and the new.* Most information systems are answer-based, and support the re-use of results that have been gathered for other purposes by other people. Gaining higher precision in data-based models and increasing the correspondence between such strategies as matching cognitive maps and the environment that is being mapped are the dominant goals of knowledge-based information systems. There is little place in these systems for the emergence of creativity and the new. This situation as expressed in GIS first came to my attention through a paper by Schmitt and Brassel (1996). In contrast, the human-centered view of information stresses that information processes are continuously creative. Dervin states that people should be aware that they are always engaged in information design (1999). Couclelis and Gale (1986, p. 9) assert that “the possibility to create new concepts by combining existing ones is among the most striking properties of cognition.” The affordance of spaces for creativity and the new should be among the objectives of information systems design. This is a subtheme throughout the present discussion.

Future Work

Based on the results reported here, future work is suggested in many areas. First of all, the workspace is not yet complete. Explicit and consistent assignment of meaningful regions and relationships, in keeping with the affordances listed in Chapter 8, has not been accomplished. Branching trees and dendritic structures, intimated in the originating graphical concept (Figure 1) have not been included. A consistent symbology

has not been devised, and identification of these relationships and symbols by means of a legend is not done.

Most of the choices related to these features, because they involve the arrangement of meaningful relations, will depend on particular applications to which the space is put. At least one example that exhibits how choices could be made in these areas needs to be constructed. The conceptual nature of the space, given the particular structures that are included in the present instance, should allow the creation of a wide repertory of choices.

This workspace offered here is a visualization that uses relationships implicit in related geometric figures. The primary relationships are meaningful, or semantic, and these can be classed among the “nongeoreferenced visualizations” being explored by the ADEPT group (Alexandria Digital Earth Prototype Project) (Ancona, Freeston, Smith, & Fabrikant, 2002, p. 205 ff.). The importance of research in visualization for non-geographic information was outlined in a recent review article by Skupin and Fabrikant (2003) that outlines a research agenda for cartographers in this field. The present outcomes point toward further exploration of visualization options. For instance, the “spring models” described by Skupin and Fabrikant (p. 103) could be candidates for managing the visualization of the tension elements in the tensegrity figure.

Nearly all of the topic areas touched on in this research merit further investigation. In particular areas the limits on my understanding have become very clear, such as comprehension of the concepts behind Shannon’s approach to information. Further investigation of the dimensions of the concepts and metaphors set out in Chapter 2 will also help in making my own vocabulary more consistent. The concepts of information and communication are intertwined in the Shannon model; now we can see that communication is just one of three main facets of the information concept. Keeping

these distinctions clear should help in developing a consistent vocabulary with which to speak of information processes.

I plan to look again at the heuristic methods suggested in in Polya's *How to Solve It* as a guide for future restructuring of the space (Polya, 1946/1957). The first candidate application that suggests itself is the construction of a "question space" that corresponds with the concept of question-centered learning environments set out in Chapter 6. The use of the word "heuristic" in naming this workspace is a gesture toward the question space concept. The term heuristics refers broadly to problem solving, both in terms of evaluating problems as they present themselves, and in terms of evaluating possible alternative solutions when complete knowledge is not at hand. The autonomous creation and management of such problem-solving spaces is not far removed from the structuring of a question space that might serve as a template for learning and discovery purposes generally.

Because the question space concept seeks to maintain autonomy of questions and questioners, but bringing communities of questions together into proximity and juxtaposition for mutual discovery, an important future advance will be designing a means for federating workspaces. One approach to integrating conversations across communities of interest (such as land use planners on Maine islands, citizens of coastal communities interested in balancing commercial uses of marine resources with sustainable conservation, and scientists located in research centers) that was discussed within New Directions Downeast (NDDE) involved use of the emerging Topic Map standard (Biezunski et al., 1999). A summary of part of the NDDE discussion is available at (New Directions Downeast, 2002). In particular, the XML version of Topic Maps, designated XTM, was explored and a document outlining how this approach could be implemented in this setting was written by one of the developers of the XTM standard,

Sam Hunting (2002) Explanation of topic maps in practical terms for implementers may be found in Park and Hunting (2002).

A topic map approach also is a good candidate for purposes of federating the heuristic workspaces that are proposed here, through identification of subjects they may hold in common. The topic map approach has been described as subject-centered, as distinguished from the more established “resource-centric” approach to data discovery as expressed in the use of metadata. “It is normal to think of metadata as being somehow ‘in orbit’ around the data about which the metadata provides information” (Newcomb, 2002, p. 40). Alternatively, the “topic maps paradigm recognizes that everything and anything can be a subject of conversation, and that every subject of conversation can be a hub around which data resources can orbit” (p. 43).

Topics as found in topic maps are local expressions of subjects, generally defined as being anything that can be the subject of a conversation. These may or may not be digital resources, and may be systematically defined as in controlled vocabularies or based in agreements involving local participants. These “subject identity points” can be used as binding points that not only can connect topics across conversations (or workspaces, or digital documents generally) but can serve to merge them if certain minimum conditions are fulfilled. The topic map approach relates what can be thought of as three kinds of spaces, in this case represented by the workspaces and its contents (symbolic tokens, that in the topic frame are the topics), the set of subjects and their definitions, and the topic map itself that serves as federating utility. Part of the advantage of the topic map approach is that these spaces are not necessarily discrete, but may exist in various degrees within each other; a topic map may overlay a single workspace or a set of them, subject identity points may be topics within a workspace, and so forth. The particular arrangement would be the result of design choices for the particular application at hand.

The tensegrity concept has been used by several authors toward discovery of new organizational forms and toward optimizing creative working relationships among people in existing organizations. Stafford Beer's Team Syntegrity (Beer, 1994) seeks to exploit the dynamism of the tensegrity toward self-discovery within organizations. The workspace as structured here could conceivably be put to use in managing and documenting the group exercises conducted by Beer and his group. Anthony Judge has been suggesting for many years the development of "tensegrity organizations" that would go beyond the limitations of hierarchical and network organizations. Judge's description of the evolution and dimensions of his concept (Judge, 1979) shows a striking resemblance to the progress of thought that has resulted in the present outcome. Extending applications of the workspace into support for the development of tensegrity organizations is to be counted among possibilities for further work.

One of the motivations for creating the workspace was the quest for a more robust environment for visualizing the relationships among code terms for purposes of qualitative text analysis. One particular research group has been identified, Busch and colleagues in Australia (Busch, Richards, & Dampney, 2001), who have undertaken several related long-term studies that appear to have made use of many of the methods attempted here. They report the use of the text analysis software Atlas.ti which allows network representations of the relationships among code terms. They have assigned dozens of terms to each of two broad classes, "articulable tacit knowledge" and "inarticulable tacit knowledge." They emphasize that their concern is not data or information, but "knowledge, that combination of data and information with attached human processed meaning. In other words we consider knowledge to incorporate a 'tacit' component, whereas information is purely articulate in nature and words. . . . It is tacit knowledge, which underpins much of our understanding of codified knowledge. In other words, what begins as a pool of tacit knowledge, leads to some becoming articulated,

then categorisation and finally codification based on emergent principles taking place” (p. 39). Through coding of “64 primary text documents, which contained separately the refined definitions of previous author’s attempts at defining this knowledge type” they derived a “region occupied by tacit knowledge . . . together with the implication of some diversity in the term’s meaning” (p. 40). Seeing this research program and result are encouraging that the methodological approach I have taken to this point, for the empirical portion of this study, can be the basis for further work along these lines.

A theme that has recurred throughout this paper points toward relating the physical-geographic world with the social-cognitive world through one consistent coordinate system. Existing GIS does this in some measure by creating a detailed and accurate geographic base to which various attributes and features are related. The non-geographic attributes are in a sense conceived to be appendages and subsidiary to the geography, which is the most stable part of the structure. Most people, however, view the world the other way around, from the perspective of their own social and cognitive understandings or “positions.” Recent work in the geographic information sciences points toward strategies for relaxing the dominance of the geographic base in creating a unified, coordinated system of representations. This particularly includes the work of researchers into “geodesic discrete global grid systems” (Sahr et al., 2003) and “planetary polyhedral tessellation” (Dutton, 1991; 1999). They are investigating the use of global coordinate systems based on regular polyhedra, as a complement to those based on traditional latitude and longitude. Of particular interest here is the idea that global geographic polyhedral projections could easily be incorporated into the proposed heuristic workspace. Two of the figures already included in the workspace structure presented here, the cuboctahedron and the icosahedron, have already been used for such projections by R. Buckminster Fuller, with more contemporary implementations under development for purposes such as global environmental monitoring. These researchers all

acknowledge the work of R. Buckminster Fuller in terms of inspiration, as is the case in the present work. A direction for future work would be toward integrating these approaches.

The availability of Axon as an environment for the workspace was a critical factor in its realization. The figures that have been constructed here are an innovation in the use of the multilevel undifferentiated digital space provided by Axon. These figures have been shared with Chan Bok, developer of Axon, who has included a sample polyhedron (dodecahedron) among the templates that are now distributed with Axon. The figures of the workspace will be distributed in a forthcoming release of Axon, making them available to users of this software worldwide. It is hoped that evaluation of the potential of this approach will be aided through expected feedback from Axon's active user community. There is a possibility that Axon may be modified in the future to support some operations that are not possible at present in that environment, such as reversal and rotation of figures.

Finally, cooperative work will continue with the marine geologists, community planners, art historians and others who have been part of the New Directions Downeast project. Motivation for much of the thinking and its products as reported here was derived from the problems and goals expressed in NDDE, and these remain. There is an emerging effort to supplement the Marine Realms Information Bank with a "discourse engine," that bears similarity with what are called "interactive learning environments" and "question spaces" here. It is hoped that continuing cooperation with these developers will allow the emergence of an approach to information management, discovery and creation that inclusive of the three fundamental aspects of communication, documentation and learning.

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APPENDICES

Appendix A

SPATIAL TERMS FROM CODEBOOK 3

Items in Caps are transfers from AnSWR; items in lower case were added during development of Codebooks 1-3.

Absolute	destinations	Indexical Expressions
Access	Dimensionality	information flows
adjacency	dimensions	Inside / Outside
Allocentric	Directions	Intrinsic
Asymmetries	Distance	Invisibility
barrier processes	Districts	Landmarks
Barriers	Down	Local
Borders	Edges	Locales
Boundaries	Egocentric	Locations
Centrality	Elsewhere	Lynch's Elements
Chorography	existential space	Map and Territory
chorology	Figure-Ground	Mapping
chronotope	Frames of Reference	Mental Tours
Conceptual Landmarks	Friction Surface	Names and Naming
container / contained	Front / Back	Near / Far
schema	Geographic	Neighborhoods
Contiguity	Geometrical Space	Nests
contiguity processes	Here	network processes
Coordinate Systems	Home	Networks
Deictic	Horizon	Nodes

Objective Expressions	Situation
one-hour rule	Size
Orientation	Social Inclusion and
Origin	Exclusion
Passageway	Space
Paths	Space and Time
percolation up	spatial analysis
Periphery	spatial transfer
Perspective Systems	processes
Perspective Taking	territories
Perspectives	There
Place Names	Topistics
places of thought	Topography
Places, Place	Topography 2
Private	transparency
Proximity	transparency tests
Reach	Up
Referent	verbal geography
Regions	Verticality
Relative	Visibility
Relatum	Visual Space
Representative Space	Way
Retinal Space	Window
Right / Left	
Scale	
shortest distance	

Appendix B
PERMISSIONS

Permission to reproduce Peter Bennett's untitled illustration that first appeared in (Lessig, 2000, p. 27) was obtained by electronic mail. Permission was requested and received July 30, 2003. The permission letter reads as follows:

Wed., 30 Jul 2003 12:04:20 EDT

Paul,

I grant you permission to use the requested illustration (March 27 - April 10 American Prospect, page 27: emptying basket of bits into a machine) for a one time usage, with the understanding that you will not profit from its publication.

Now that the legal part is done, thanks for including my work in your thesis.

Good luck!

Peter Bennett

In a separate message Mr. Bennett stated that this illustration is "untitled."

BIOGRAPHY OF THE AUTHOR

Paul Charles Schroeder was born August 12, 1946 in Chicago, Illinois. After graduating from Shorewood High School in Wisconsin he pursued his undergraduate degree in Political Science at the University of Illinois in Urbana-Champaign, where he graduated with highest honors. The need to perform alternative military service as a conscientious objector during the Vietnam War era brought his first attempt at graduate study to a close. After fifteen years working outside the academic world mainly in the building trades, he re-entered academia as a library student at Simmons College, Boston. Beginning in 1986, Paul worked as an academic librarian for nine years. While serving as President of Maine Academic and Research Libraries (1994-1995) he led advocacy for expanded telecommunications services for Maine libraries, and received the Presidents' Award for Outstanding Service from the Maine Library Association and the Maine Educational Media Association. Paul has lived in Orono, Maine for the past 17 years with his wife Mazie Hough and their daughters Emma and Greta Schroeder. Paul is a candidate for the Doctor of Philosophy degree in Spatial Information Science and Engineering from The University of Maine in August, 2003.