with more than one race. Chapter 8, "Conclusions," discusses residential separation and enclaves and attempts to give some explanations.

The maps in this work are clear and attractive. The large, landscape format is well suited to the area and allows the maps to be shown at a reasonable scale. The colors used on choropleth maps are pleasing and easy to distinguish from one another, and the base map is useful without being obtrusive. There are 15 small, color illustrations within the text that show typical scenes from different ethnic areas. While the work would not suffer from their absence, they do add color and a feel for the diversity of Southern California.

The text is clearly written and describes the patterns seen on the maps with explanations. All terms are defined, which is useful to a reader who might not be familiar with the distinctions between Hispanic and Latino, for example. Problems with creating the maps because of weaknesses in data or overlaps of ethnic identity are explained. There are extensive endnotes for each chapter and three pages of references at the end.

Overall, this is an excellent work and would serve as a model for similar atlases of other CMSAs. It will be of interest to anyone involved in population mapping, demography, or planning.

Representations of Space and Time
By Donna J. Peuquet
New York:The Guilford Press, 2002. ISBN 1-57230-773-0 (hardcover)
xii + 323 + references + index
(no list of figures)

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Donna Peuquet's *Representations of Space and Time* is an overview and synthesis of our understanding of space and time: what they are, how they are represented in minds, and how we might most fruitfully represent them in computers. Covering all of that in a single, highly readable volume is a challenging undertaking for author.

The task undertaken in this book, to offer a compact yet satisfyingly full treatment of what we understand of space and time from work in philosophy, psychology, cognitive science, computer science, and geography, and to tie that into the GIScience enterprise, is ambitious. There is a lot of ground to cover (indeed, the publisher refers to the book as "sweeping" and a "*tour de force*"), but the route is direct enough, and both the journey and the destination are worth the effort.

Taken as a survey and a summary, the book serves as a guide to the large and disparate literature, from several disciplines, that addresses thought about, and representation of, space and time. With that overview achieved, Peuquet invites us to look ahead with a more firmly situated view of the GIS enterprise. Her ambitious route in tying together our understandings of cognitive representations in minds and of computer representations in GIS brings us to a vantage point from which to develop a roadmap for future GIS research.

The Contents

The introductory chapter situates the book in the effort to create a conceptually coherent framework for the representation of space and time, as an exploration of both cognitive and formal representations of geographic space and time. The rest of the book is structured in two parts.

The first part of the book deals with knowledge representation in human minds. It integrates material from the beginnings of western philosophy through recent psychological research to define space and time, to distinguish them from their representations, and to examine how people acquire, store, and use spatial and temporal knowledge. The treatment is broad and dense.

The second chapter, "Representation versus Reality," offers definitions of "Space" and "Time," provides a broad survey of how they have been conceptualized from early mythology through modern science, and draws out common threads from that cloth. The swath is impressive, weaving together the contributions of Hesiod, Democritus, Epicurus, Plato, Aristotle, Copernicus, Galileo, Descartes, Newton, Leibniz, Einstein and Minkowski on the nature of time and space with those of Kant, Locke, Werner, Piaget, J.J. Gibson, Marr, Talmy, Herskovits, and others on space and time as context for human understanding. Common threads are extracted: that views of both space and time share two dualities (discrete vs. continuous; and absolute vs. relative conceptualizations. "A fundamental thesis of this book is that absolute and relative views of space and time are complementary and interdependent. The same holds true for continuous and discrete views of space and time."

Differences in the measurement and conceptualizations are also

noted (absolute time is progressive, while absolute space is not, but relative space and time are both amenable of similar patterns).

This survey is expanded in the remaining chapters of the section. Chapter 3 deals with the overall process of learning about one's environment and acquiring knowledge of it. Here, contributions of Hegel and Cassirer are woven into the piece alongside Werner and Piaget, and an accumulative process, joining direct experience and more abstract experience, mediated through symbols, emerges. The geographic in this is exemplified by Siegel and White, and by Golledge. Given the universal types and sources of knowledge, the book moves on to its storage.

Chapter 4 deals with some elements of the conceptual structures for storing world knowledge and what the ontology of spatial things tells us about them. It notes the embodiment of spatial knowledge, touching on biologically-motivated parallel distributive process models of cognition, and passing into the characteristics and constraints developed in the mental map literature to pull out the structures that they indicate. The roles of categories, schemata, frames and other such structures used in thinking about things geographic are examined. Philosophical and psychological threads from Rosch, Tversky, Lakoff, Lynch, and others come together to underwrite a core idea of the book—that mental representations of spatial and temporal knowledge are multi representational and dynamic. Further, they develop through and support the integration of inputs of various kinds.

The next two chapters examine how we learn and integrate world knowledge from direct experience. Chapter 5 expands upon the mechanisms for acquiring world knowledge through direct experience. It draws on the work of J.J. Gibson and Marr, among others, to describe the interaction of cognition and perception, and to indicate how the internal structures influence the apperception of the external. Chapter 6 extends this to explore thought on how sensory data can be taken from simple observation to become understanding. Here, imagery and metaphor are invoked as familiar examples of the explorative and generative mechanisms, thought processes, by which connections are made between observations and mental structures to build the richly inter-related structures that constitute intelligence and understanding.

Chapter 7 considers the role and processes of acquiring geographic knowledge through indirect experience, i.e., through graphical and spoken and written linguistic representations. Peuquet argues that graphics of various types tap into the ability of the human visual system to derive pattern and coherence instantly and further, to feed the conceptual structures. The facts that linguistic representations and graphics, including pictures, diagrams, maps, and other types are products of human agency, are generally abstractions from someone's (culturally and physically embedded) perceived reality, and may be inaccurate, is noted but the problems this implies are tacitly left to the sense-making processes of the mind to arbitrate.

Peuquet argues that maps convey meaning through both their algebra-like and their visual image structure.

Reviewing work by Levy, Herskovits, Talmy, Lakoff, Jackendoff and Landau, and others, Peuquet delves into how language represents the content of mental structures that note spatial relationships and what it reveals about those structures. Further, the value of processes and mechanisms that facilitate the leveraging of society in creating individuals' spatial knowledge stores is clear. It is clear too that a great deal of the mental content that many of our minds hold derive from indirect experience of space and time. It is clear that graphics and language intertwine to provide a richer yarn to be worked into the weave of spatial-temporal knowledge and that the examination of these external manifestations gives insight into the internal representations.

The eighth chapter goes further in describing how spatial knowledge is encoded in minds. The debates of the past several decades on how spatial information is encoded in minds, i.e., imagery vs. propositional vs. dual-encoding vs. homomorphism debates, exemplified in the works of Kosslyn, Pylyshyn, Pavio, and Johnson-Laird are worked-over and a higher-order perspective assumed: the exact form of the internal representation is probably impossible to determine but, whatever it is, it supports at least several functional modes of use, each with distinct advantages and disadvantages. Evidence from several studies is mustered to support the notion of separation of "what," "where," and "when" knowledge is one of the key properties of encoding. Doubtless, Figure 8.4 is worth more than a thousand words; likely a thousand lectures will find it a useful summary of the first half of the book. It may well rise to the level of use made of Robinson and Petchnik's simplified version of Kolacny's or of Muehrcke's diagrams of the cartographic communication model.

By page 205, the first half of the book has taken a direct and detailed trip through more than two millennia of thought about space and time, and provided a convincing account of how we

experience and think about them. It is a compelling and well aimed coverage. Those who are unfamiliar with this literature will find this a dense stand-alone treatment and an inviting guide to further reading. Those who are familiar with this literature will find the organization of this explication beneficial. It would be the backbone of a pretty demanding graduate level reading course on philosophical and psychological underpinnings of spatial cognition and hence of fundamentals in geographic information science.

The second part of the book deals with the formal computer-based representations employed in using computers as tools for storing and processing spatial knowledge. This may be more familiar terrain for most GIS practioners, but the focus is different from the usual prescriptive (here's how we do GIS) one. Peuquet's objective is to apply what we know about human spatio-temporal cognition to move toward a more human centered approach to handling spatial and temporal information than is currently practiced.

Chapter 9 raises a number of questions about how best to use computer technology to display information and to solve problems involving the manipulation of spatial and temporal information. Examples of several paths that have been explored are offered: Dana Tomlin's map algebra, spatial and temporal extensions to SQL, application of human-computer interaction principles and of developments in artificial intelligence particularly computer vision, expert systems, and natural language processing knowledge discovery/data mining/pattern noticing.

The new tools suggest many new opportunities, but the differences between these and earlier tools suggest that we need to think through how computers can more effectively be used. One possibility is to note the similarities between the cycle of knowledge acquisition in cognitive and scientific contexts.

In chapter 10, the perspective that computers are best thought of as a medium comes to the fore. The medium brings together (distributed) databases and display screens with interactivity. "The greatest potential power of the computer as a representational medium derives from its dynamic, conceptually multidimensional nature, and its ability to produce multisensory output" (p. 221). Via the computer, maps take on more of the exploratory role in addition to the presentational role. Most of this is old hat to cartographers who habitually sketch-out distributions and patterns as a way of understanding their date. It is now a common-place that maps serve two functions: areal storehouse and source of distributive pattern—that has not changed.

Chapter 11, "Storing Geographic Data," provides an historic overview of current approaches to representing digital geographic data in computers. It sets a discussion of datamodeling within the context of levels of representations within a database management system (physical storage, conceptual schema, and subschemas). The formal cleanness of current database design is contrasted with the relative *ad hocery* of the various vector and tessellation data models employed in GIScience. Way-points of the past thirty years, such as SYMAP, GBF/DIME, POLYVERT, and Morton indexing serve as landmarks in an emergent landscape. It has worked, and can be described in a surprisingly cohesive framework, but it still lacks a comprehensive theoretical foundation.

Chapter 12, "A New Perspective on Geographic Database Representation," attempts to say what that foundation might be and is the core of the book's contribution. Stating with the lessons learned in the raster versus vector debate (they both can do the job and they each have advantages in different specific applications), noting the diversion to hybrid models and that most commercial systems now do both and also integrate relational database technology, and tying in calls for both new analytic techniques (e.g., inductive exploration as in Openshaw's Geographical Analysis Machine) and the desire by some to represent human concepts of reality rather than cartographic representations of it, the first section of the chapter sets up a metaview from which one can ask: what should the theoretical foundation be?

Gamely taking a stab at an answer, Peuquet identifies characteristics that the theoretical foundation framework should have in support of representation (allow effective representations for various specific uses, be extensible, formalize our intuitive notions, and support new insights into spatial cognition), and suggests that frames and object-oriented techniques (which ease systems development by making their components more like our normal conceptualizations) provide a potential direction. They could be used to support the dual ontological models (continuous and discrete) of space and time, as well as the taxonomic and partonomic relations among objects, with a single underlying data store which incorporates locational/where, temporal/when, and thematic/what data. This notion, dubbed the pyramid model, has been used to develop a working prototype, the Apoala system (Mennis, Peuquet, and Qian (2000)).

The bigger picture that emerges is that geographic databases can partake in, and benefit from, the hierarchical organization, abstraction, and associative retrieval which characterize the multi-representational model evident

in human spatial and temporal cognition.

Chapter 13, "Interacting with Databases," delves into advances in interfaces to indicate how linguistic and visual interfaces will provide richer and easier access to information in geographic databases. It ranges over query languages, computer graphics, visualization, and virtual environments and emerging technologies for interacting with computers, and makes the point that "the true power and utility of database and information systems...lie in the ability to perform analysis," here characterized as exploration, explanation, prediction, and planning. Peuquet seems hopeful that the semantic problems that arise in these higher-level operations can be addressed by the coupling of richer data models with rich interaction.

Chapter fourteen, "Issues for Implementing Advanced Geographic Databases," revisits some of the sticky wickets in spatial and temporal information systems that must be navigated simultaneously. These include dealing with vagueness, uncertainty, and imprecision in data, as well as working out the higher-level issues in getting computers to be fuller partners with their human users. Handling time satisfactorily requires that something beyond the bitemporal model be integrated with the handling of space. Handling the inexactness inherent in spatial-temporal databases is also required. Formalizing the ontologies needed to support advanced data models and interfaces poses another fundamental challenge, and one in which there is lack of agreement on the best approach. Promising advances in computational implementations suggest that sophisticated programming can raise the level of "artificial creativity" in tasks performed by computers, but leave little doubt that humans are still better at some things. There also remains the issue of bringing database technology to the point of embracing the need to handle the desired richer representations while maintaining reasonable performance.

Finally, in a short epilogue, Peuquet re-gathers the insights of the past to assess the prospects for the next ten years of geographic information science research. The needs to consolidate and extend recent work on formal ontologies and the capabilities of experimental systems are noted and the challenge issued.

Assessment

The principal contribution of this book is in pulling a wide range of material together to produce a coherent view of thinking on space and time and how insights into the mental and computer representations of them can be brought to bear on further development of spatial-temporal database technology. It is geared to those interested in wrapping their minds around GIS research frontiers and working on its future development—not those wanting to use current GIS technology, though they too would benefit from it.

This is a great book; it succeeds even where it can only point toward possible answers to the questions it raises. The book occupies open ground within the thicket of GIS books. It stands alone between the pragmatic explications of current GIS practice exemplified by deMers *Fundamental of Geographic Information Systems*, the more computationally motivated volumes such as Worboy's *GIS: A Computer Science Perspective* or Laurini and Thompson's *Fundamentals of Spatial Information Systems*, and such conceptually motivated volumes as Chrisman's *Exploring Geographic Information Systems*. The degree of integration of human-centered disciplines, principally philosophy and psychology, set it apart. It is neither a textbook nor a how-to text, but rather a what-to text in the sense of pointing out what are the next steps that GIS must take to move toward its promise.

This is an intriguing invitation to conceptualize the next generation of GIS. It reminded me of the questions that interested me in GIS and served as an intellectual spring tonic. I will make it required reading for my graduate students.

Critique

This book is a sufficiently important contribution that I am wary of offering any criticism of it at all. But that would be boring, so I'll share a couple of questions that remain for me.

While the suggestion that computer representations of space and time will be more advantageous if they are more like human mental representations is plausible, it is ultimately taken as an article of faith. This is quizzical given the notion that the strength of the human-computer partnership lies in the former's creative flexibility and the latter's indefatigable unerring attention to computational detail. This is compounded by the implication "that the deterministic and closed-world comfort of a *mathematical* basis for representation is insufficient." It leads one to wonder whether the partnership might be weakened by putting more of the human's fallibility into the machine. Peuquet believes that it won't. I hope that she is right. I'm not so sure. Time will tell.

The problems raised in the penultimate chapter clearly identify research directions that will occupy a number of disciplines for several decades. They already have, and while progress seems to be made, fundamental problems remain unsolved in general. The epilogue seems a thin answer to this concern. The value and intellectual pluck shown in casting these problems in this framework

is nearly as remarkable as Peuquet's resolute determination that we can make progress by working on them. Turning over the material in this book reveals both progress and potentials. Putting all of this together in one cohesive picture is remarkable.

Minor Complaints

The title is ambitious and perhaps misleading: the work is at once more focused and broader. The title may suggest to some that it will catalog all of the ways that space and time have been represented as in art, maps, etc. It contains very little of that. Rather the book surveys philosophical, psychological, and computer science thought on mental and database representations of things that are situated and related in both space and time. Many kinds of representations of them are barely considered: artistic renderings or the various approaches that cartographers have taken to trying to show both space and time.

The large number of back and forth references within the text become a distraction, but, in fairness, may be the only way to meet the case. The various threads of thought that are woven into this piece each are developed in their turn, but the relations among them might have been lost without explicitly noting the connections. Still, the number of forward and backward references within the text suggests that a hypertext version may have been more natural.

Cataloging what we know about mental representation of space and time leaves one with the dismaying realization of how little we really know about how all of this works.

Conclusion

This is an important, even a great, book. It covers a lot in a thin volume. It will be valuable for organizing graduate seminars on geographic information science and on spatial cognition for years to come. The book organizes several threads into a coherent cloth. It reflects Peuquet's faith that these things can work.

This book is deep-thought provoking. It surveys and synthesizes a pile of far-flung literature, summarizing and raising questions with it as it goes. Psychology, philosophy, computer science, and even cartography are brought togehter. In the process, it leads a reader through the field of GIS in a way that provides understanding far deeper and insightful than any of the GIS texts that are out there. It shows the conceptual roots of representing geographic phenomena in computers. It brings one to the edge of the research frontiers. And points the way ahead.

map library bulletin board

From Christopher Mixon, new Map Library Bulletin Board Editor.

Recently I went on a ski trip to Northern Wisconsin and on my way I spent four nights with friends in Milwaukee. I had made plans to meet a fellow map cataloger from the American Geographical Society Map Collection and my former cartography employer for lunch. Of course we chose Indian cuisine, who wouldn't? After lunch I visited the AGS Collection for a quick tour. Though I had used the AGS collection as a UW-Milwaukee geography student, I had never had the tour. While at the AGS, I was able to speak with some colleagues I knew and was introduced to several others I did not know. As I spoke to the folks at the AGS collection, I noticed that almost three hours had slipped by. I was struck by the fact that librarians (map librarians at least) have a lot to talk about.

As your new Editor of the Map Library Bulletin Board for 2004 through 2006, I invite you, who are involved in library map collections, to tell your story. Tell us about a conference or workshop you have recently attended. Submit your research papers. Many articles in past issues have described map collections in great detail, from their histories to circulation policies to notable collections within. We all want to know how other institutions deal with issues such as cataloging, storage, maintenance, etc.

One issue that came to mind for this column was the name. A bulletin board might be fine if you are selling puppies but not so for posting your scholarly research. Perhaps a new name for this column is in order. Just a thought – let me know what you think.

Please submit your work to me, preferably as an email attachment, to **mixonch@auburn.edu, or in the body of an email. Submissions via snail-mail are gladly accepted and should be sent to me at RBD Library, 231 Mell St. , Auburn University, AL 36849-5605.**

Christopher H. Mixon