Archaeological Data Spaces: Spatial Aggregation and Large-Scale Knowledge Environments

Cornelius Steckner

FOCAS, D-50996 Cologne, Etruskerstr. 22, Germany

e-mail: csteckner@hotmail.com

Abstract

Does archaeology only apply computer methodologies? In the field of spatial exploration archaeological practice offers skilled methods that computer sciences should adapt. Among the adapted is the archaeological shape of the description vocabulary. This is a text based method used to describe and classify shape amalgamation as generalised cylinders. This classification allows the aggregation of the object space to proper words and for computer-code to improve AI based robot vision. Another specific archaeological spatial aggregation describes the process of civilisation. In this view exhibitions and museums are multidimensional and multi-user spatial aggregations designed to meet socially accepted knowledge and information metaphors. Such archaeological conceptualisation is also increasingly meeting the demands of the forthcoming distributed data space protocol (DTSP) and related large scale virtual environments (X3D).

Key words: spatial aggregation, distributed space protocol, large-scale virtual environment, multi-user environment, multi-perspective environment

"We believe part of this ability to visualize and imagine must consist of skills to generate images, discover structures and relations in the images, transform the structures, and predict how the structures respond to internal dynamics or external forcing."

Yip, K. and Zhao, F. 1996.

1. Data space

By definition data space is a storage area for data, locally stored or distributed over the net. With the appearance of new protocols such distributed data spaces are increasingly becoming seen as environment-like navigable multi-user virtual information spaces. They are designed to address the human skill to discover structures and relations in the environment as well as related spatial aggregations of different density and dimensions. The most complex aggregations are architectural knowledge spaces (libraries, museums, exhibitions) which combine different space aggregation density and different media; thus the word "Europe" is of higher density than the map or the movie. The computer monitor, as the most flexible media for the mind, gives access to verbal, visual and virtual knowledge spaces. However, it has its communicative limitations as a human computer interface. Any screen addresses a specific mode of visual cognition. The screen forces the user to keep up a specific embodied access of the time-sequenced information. The screen communicating text, space and animation uses only 2D-planes. But the user's text and image reading competence makes the 2D-front-end become a universal display of multidimensional data spaces. In this event visual cognition is a mix of natural environmental and trained cultural information access. In this respect the hidden communicative basis is a wide range of common spatial metaphors used to aggregate space. The map metaphors and schemes use generalisations, and intuitively the user reacts on the level of detail in order to obtain an idea of the scale. As a consequence, metaphors such as globe, map and perspective tell us about the steps in the representation of geography related numeric data, dependent on the knowledge of the user and his communicative skill.

1.1. Spatial metaphors of communication

Any chosen metaphor of communication will help the user to find the right motivational arousal to discover structures in the aggregation by appropriate modes of access behaviour. The map is just one of these metaphors (Chalmers 1993) that offers access to large-scale environments. The method is generalised and the pattern is the page in front, ready to read. Accordingly, the text is scaled and oriented. Information technologies apply the page and illustration metaphor to the screen. Other metaphors, taken from the civilisation environment allow for a dynamic spatial access. Further architecture-like metaphors are more static but improve the information access by active flyover and fly-through modes of knowledge access. The communicative architectures of virtual information spaces (Daessler 1998) are so far classified as:

- panorama screen presentation,
- regular matrix object representation,
- virtual and abstract landscapes for environment like exploration,
- shaped objects scattered into gravity spaces,
- museum like multidimensional and multi-perspective knowledge spaces.

1.2. Virtual information space generation software

Most of the related information technologies are freely available as research programs for the UNIX/Linux environment, covering several communicative architectures and numeric information related data types (Daessler 1998). VisDB and Xgobi/XGvis import supplemental GIS data; other information explorers produce maps of their own (WebSom). Vis5d and VTK focus on environmental streaming processes, while several image understanding environments (IUE, Khoros, VTK, SNSS) are designed to analyse image records of spatial situations, or use agents (http://agents.umbc.edu/introduction/) for similarity research in stored CAD vector data and bit mapped images (SimilaryResearchSystem

S3). A good tool to study bookmark-based spatial exploration is the VRML document search engine (http://fabdo.fh-potsdam.de/infoviz for UNIX and Windows) and "The brain" (http://www.thebrain.com). These produce private information spaces that do not socially communicate as agent based systems (Thomas, 1996). Surveys on spatial information and knowledge visualisation can be found at the following homepages: http://fabdo.fh-potsdam.de/infoviz; http://www.dbs.informatik.uni-muenchen.de; http://www.hitl.washington.edu/projects/knowledge_base/research.html). The museum-style X3D knowledge representation of information spaces (http://snm.hgkz.ch/%7Emaja/begin.html) is forthcoming with the newly available data access and retrieval technologies (http://www.pitt.edu/~korfhage/viri_bib.html).

1.3. Forthcoming protocols generating spatial aggregation

The information technologies applied to spatial reasoning are referred to as "drill-down data mining technologies". The distributed data spaces and the distributed users need defined spaces of aggregation in which to meet. Consequently the spatial aggregation may be a multi-user world where agents meet. This is the tendency in the development of information technology, where the new Data Space Transfer Protocol (DTSP) meets the forthcoming development of the X3D modelling and Virtual Reality Transfer Protocol (VRTP) in support of internet 3D graphics and large-scale virtual environments (LSVE). This tendency toward LSVE meets the space-related methodology of archaeology in several aspects. Hollerbach has already focused the archaeologist's skill to discover and to describe time related spatial structures of pottery in order to improve robot visual environment cognition (Hollerbach 1975). He can show that the description and identification is based implicitly on the concept of generalised cylinders, reducing the closed surfaces of the ceramics according to cylindrical co-ordinates. In this space any object is defined by a rotating distance measure running along the axis. If the axis is straight and the distance constant, a 2D outline is sufficient to describe the entire surface. The related verbal description of these shapes uses a hierarchy according to body, neck, lip, foot and handle. A mere 105 terms were sufficient to describe and to identify 42 types of pottery. From this approach a concept of amalgamation emerged, which could describe and identify more complex structures by supplemental indentations and protrusions. Accordingly, the scientific skills used to detect structures and relations in all sorts of 3D structures and their images are a fascinating resource for applied spatial reasoning of different aggregations and scales (http://www.cs.albany.edu/~amit/spatsites.html). As a consequence archaeology is not just a field that adapts computer applications from other fields of research.

2. The spatial aggregation of archaeological space

Excavation documentation techniques are techniques that are designed to aggregate spatial information to fit the demands of printed communication. The page is the format used to combine text and numerical information with orthogonal drawings in scale, with a variety of scaled vector representations and bit-mapped perspective information.

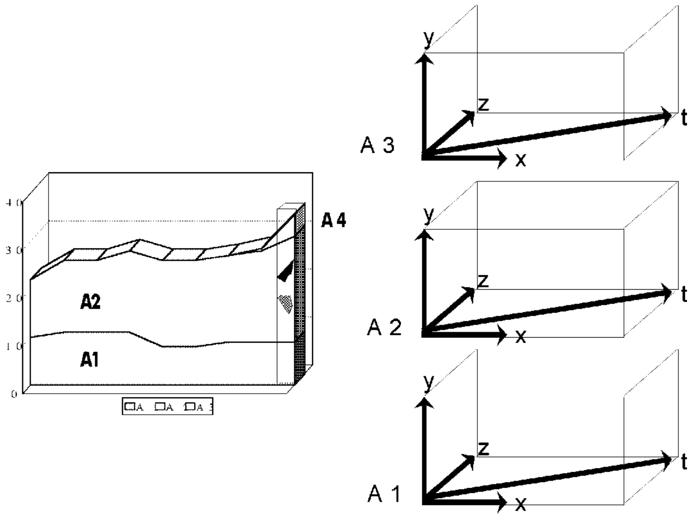

Figure 1: Strata and Sediments (left) transformed to a sequence of architectural spaces (right).

Spatial aggregation maps the strata of a site. The slicing method is illustrative for it documents every five or 10 cm on a transparent material. The result is a scaled-down 3D model of the site. Other techniques follow the strata or relate vertical and horizontal views. Slices and strata represent time, while the horizontal distribution represents the space related to a time-segment. Each stratum binds a class of relics and represents its own epoch, so each stratum has its own four world dimensions (3D + t). Accordingly, the recorded strata taken together represent a multidimensional space. By their relics the original 4D layers or epochs are conventionally restored and collected in archaeological storehouses and museums. This is where the original relics can be combined with all sorts of aggregation and site-related media in order to inform the public. But how do we express a multidimensional space?

2.1. The three age system as aggregated knowledge space

Between 1818 and 1824 Christian Thomsen (1788-1865) reorganised the Copenhagen Museum of Northern Antiquities according to the technological process of civilisation. Thus, a structure to built multi-user knowledge and information space became available. According to scientific knowledge gathered from excavations, he started his suggested tour with the Stone Age room. Then he presented the assembled Bronze Age relics, followed by the rooms with the Iron Age artefacts, each room or floor defining a knowledge space of its own. The aggregated process of civilisation became an environmental walk between ages. The walk takes time. The time consumed reflects the sedimentation of time, and the border of the room represents the border of the ages (Hotta 1992, Steckner 1995). Recent displays present spatial aggregation by additional refinements. Some displays emphasised the geographical drill-down, adapting the cardinal points of the compass with the corners of the room. Other displays emphasised morphological representations across the epochs.

2.2. Sediment and revolution

The metaphor Thomsen used (figure 1) was not the museum as such, but an architecture to display the knowledge as regards the ages of technological progress. Technological revolutions distinguish the ages by borders which separate the civilisation sediments. In relation to these sediments the idea of ages also implicitly covered the quantitative approach in archaeology. The three main strata form the structure of a 3D stacked bar composed of three sediment layers, each of them a closed surface. Transformed to an architectural structure, the arrangement of the closed surfaces makes up the knowledge space. This architectural model of the ages became adapted by all sorts of local and world-wide museums and exhibitions, each a spatial aggregation of its own. In consequence, the metaphor became the socially adapted convention to drill-down the knowledge of natural and cultural history in a multi-user environment. Media of different intensities and of different immersiveness told the story of civilisation by the multidimensional directional walk from one age to another. Optionally, the suggestive progress became emphasised by staircases and epoch related murals displaying the revolutionary environmental changes caused by technological progress. Such ideas emphasised the epoch related change in perspective. Each epoch became its own world with its own perspective. These stacked worlds are also the aim of the recent LSVE developments. Accordingly, the museum metaphor applied to large-scale VR environments is the optimal structure that can be used to express independent worlds within a unique co-ordinate system and code.

2.3. Public access feed-back

The information data types aggregated to express the knowledge space in the beginning were objects and environmental murals, associated with explanatory texts and drawings in catalogues. Spatial aggregation remained visible in the names of the sites. Then all sorts of perspective site views, panoramas and dioramas, as well as distribution maps, explained the spatial aggregation within the refined knowledge space. The information technologies were increasingly supplemented by models, movies and animation, in order to conform with the evolving public communication style. In the refined knowledge space there is not only a response to the technological progress in public communication. In addition, public access may offer feedback to spatial aggregation. Consequently, there are remote control systems, installed to change the distribution of showcases according to the demands of the social acceptance and understanding. These systems are already in use. The Disney EPCOT, Florida, which is designed as a globe map-style interface to display future developments, continuously checks the flow of people in order to respond by immediately installed attractions to avoid a bottleneck in the flow. Similarly applied Monitoring Continuous Systems (MCS: http://www.cs.utexas.edu/users/qr/papers-QR.html) in museums may look like the Yokohama Museum. A remote control and transport system allows response to the demands by immediate changes in the spatial order of the display cases (Hotta 1992). Further automation may use optimal room position of display cases and media installations to answer both, the demands of the knowledge representation and user knowledge. Of course such spatially reacting displays may be adapted for a dynamic LSVE display. Accordingly, communicative spatial reactions to the data and to the demands of the users have to be distinguished according to their freedom within their knowledge architecture constraints.

3. From text to space and back

In communication, natural speech-dependent text-based methods dominate. This covers not only the guided tour but also the labels and descriptions in catalogues. Cinema and TV-movies also have text-based structures. In these media, the written texts are cast into pictures and dialogues. In the virtual world these stories are the human readable texts of VRML-code and the scripts of povray-like photo-realistic representations and slide by slide rendered movies. Although not always, the code is usually written in human readable ASCII format. Accordingly, it is a good idea to add a further step to link spatial aggregations and related images with data spaces. The idea is to store the original data of all sorts of spatial immersiveness in ASCII based code. DTSP aims to perform this, as does the SAMOS project (Steckner 2000). The reason behind is only the issue, which highest aggregation density and also extreme reality - the manufactured object and built architecture - may be coded by words.

Accordingly there is no qualitative difference in voice, text, bit-mapped, vector and other space representing data in the data handled by archaeologists. Each site and real world object must be identified by a proper name. The image may be scanned by laser technologies, accessed from satellite bit-maps and from outlining vector-graphics, whatever is accessible. Also, any immersive VRML space script may produce photo-realistic or, alternatively, a non-photorealistic drawing-style output. The same data sets may be filtered to stereo-lithography STL and other similar computer-aided CAD building and manufacturing processes. So the drill-down techniques are in a windup loop with the 3D manufacture data processes.

3.1. Robot and agent access to archaeological data-space

In information spaces there is not just dimensional drill-down and windup by applied filters. There are also on-top techniques available. A good example of how to envelop text space is the PUEBLO software system. This software, revealed by good educational applications, runs 2D maps or images and 3D VRML representations on top of text based Multi-User dungeons (MUD). These MUD-applications show the same levels that are found in the drill-down and windup processes and data conversion and filtering. Accordingly, any of the levels may be connected in the communication system. The remote access might be in the text level, while the action is displayed by a 3D-projection, immersive or not. The projected environments are the meeting-places of remote avatars, which are agents of the distributed users. So what looks like a remote avatar is not necessarily a remote avatar. The avatar we meet in the virtual Stone Age or Bronze Age environment may be guided by remote access. This is not certain in the long run, because the avatar may also be an autonomous virtual robot merging in real-time into the virtual environment-generating program. At which level the robot generates his own environmental map will not be certain. The orientation might derive from the MUD text code or from another level up to the video-screen the human user has access to. Equivalently, the meeting place might be an aggregation of a distributed data space.

This kind of level-incursion is the idea of X3D. The idea is derived from a virtual submarine navigation by virtual sonar in virtual waters. Accordingly there are all sorts of virtual robots exploring all sorts of data aggregation by remote and autonomous processes (http://www.robotic.dlr.de). Such robots also read the human readable codes, or they have access to bit-maps or even to the visual environment, which then becomes their data space. According to the concept of data space the natural environment is also a data space.

3.2. The real and the virtual

What would happen if we could explore information like we explore the archaeological museum? The question was posed in the thesis of Mark A. Foltz "Designing Navigable Information Spaces" (1998): Like Hollerbach (1975) Foltz also first studied and examined the human skill to orient by exhibition display, while not distinguishing information and knowledge representation. In the meanwhile the first X3D environments and related aggregated information spaces appeared (http://www.infoarch.ai.mit.edu/spaces.html; http://www.infoarch.ai.mit.edu/jair/jair-space.html; http://snm.hgkz.ch/%7Emaja/museums.html). These show the transformation of the multidimensional museum aggregation into multi-user virtual space. However, even, cyber-suits and exo-skeletons with touch force feedback will not reproduce the original gravity walk in the museum.

4. The gap in the media

There is a gap in the mixed-media presentation in real museum environments and the immersive virtual information environments. In the real museum architecture visual cognition is controlled by the vestibular system and by environmental feed-back. The key and behavioural anchors within this environment are the original physical objects. But text display read from left to right will also be an anchor to assign information and orientation (Steckner 1993). These keys allow the user to relate additional media of all sorts within the architectural framework and to switch to the new perspective of each age. The user walks through the exhibition to get an impression of the environment, or to reach a goal. He stands or sits reading a map, a picture, a text, trying not to move. The visitor perceives size and material quality of the object, i.e. its size and weight. These senses confirm and map the knowledge space. Embodied intelligence guides the user in real environments. To enhance the modes of access the museum uses space segments. The knowledge space used to display the ages of technology and style is accessed by walking. The library is instead designed to preserve books and to guide users to their content, which is read in the place. There is the cinema were people watch movies on the screen and listen to lectures with slides. Each of the architectural frameworks has its own embodied style of access. The media related differences in display architecture and behaviour settings were not realised in the early pure mental concept of AI and robotics. In consequence a change in the robot programming methods is coming, a change which will have further consequences throughout the IT field. Embodied technologies are increasingly adapted for autonomous robots, and physical modelling is increasingly applied (Fishwick 1996), even such as reading weight and measure standards from bit-mapped shape information to generate information spaces (Steckner 2000).

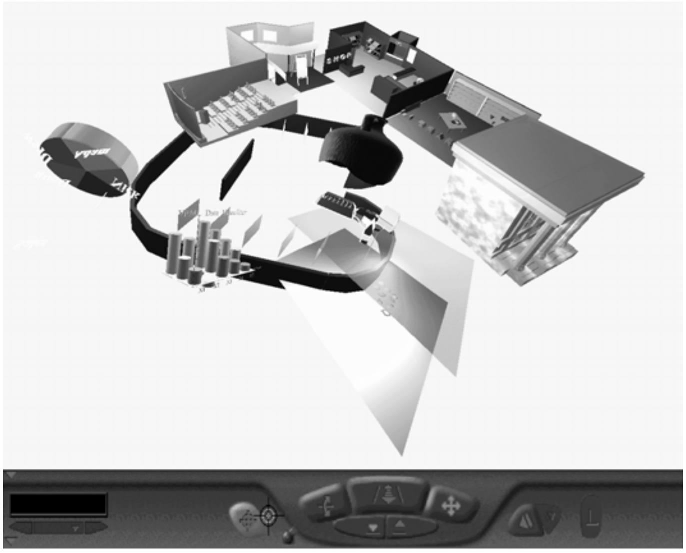

Figure 2: Layout of the spatial media and display test-bed.

5. The application

The application project designed to study the interrelations in architectural space and media access started several years ago, when I designed a media museum. There the architecture clearly showed synergy effects with the specific media, whenever the architecture was binding and separating the specific mode of access. Further research in human computer interfaces, motivational arousal, and anticipation led to an effort to analyse and to model human environmental interrelations (Steckner 1999). The application is a VRML test-bed made to interrelate specific media access styles, display styles, and spatial metaphors (figure 2).

In the present version VRML offers several features that offer a taste of X3D / DTSP LSVE-like multi-perspective virtual environments. A suggestion is to emulate the environmental switches, using a component-based virtual environment, in which components each ask for a different mode of media access, and the design emphasises the modal access. The generated world is a museum-like knowledge space displaying different information styles by an architecture compound prototype. The joined environment styles come with distinguished architectural spaces, each devoted to a dominating media. Any entrance convention is much like the opening sequence in conventional multimedia encyclopaedias, with an access-style map of the whole structure. The VRML model so far has a public entrance hall to guide the users according to their needs, a library environment to display texts, joined by a place to navigate in text-based information structures, which here are bookmarks. The tools to generate the information spaces directly from information by a similarity matrix are found in the free mSQL-based document finder (http://fabdo.fh-potsdam.de/infoviz). The text based information emphasises high contrast black-and-white text presentation, while the bookmark-converter displays navigable abstract information landscapes, where colour is also information. Then there is a cinema with seats as a hint, specialised to display movie-style information by means of an introductory movie tour through the whole environment by photo-realistic rendered presentation. The user is then taken around following the camera view and perspective. So, this place is not devoted to video-on-demand, but to the study of the differences in the information access in camera-based forced move and free navigation, all in respect to the whole architectural structure. An alternative photo-realistic slide display allows another sort of GIF-map like spatial navigation (O'Neill 1998). A show so far is outlined as complete architecture, followed by an exhibition hall with a collection of 3D site- and object-models, related photographs, and exemplary numerical and map-based information in object-style. The focus is to understand the acceptance and readability of embedded virtual real site models and object-display in relation to map and statistical display prototypes. The architectural segments are designed to answer how far real objects and abstract objects, text and images relate to each other in virtual spaces according to the access modes. The architecture of each of the rooms, according to the implemented information and display types, becomes its own environment to force the appropriate behaviour setting of the user.

References

BLOCK, A. (ed.),1990. *Cognitive models of psychological time*. Hillsdale, NJ: Lawrence Erlbaum.

CHALMERS, M., 1993. Using a Landscape Metaphor to Represent a Corpus of Documents. In Frank, A.U. and Canorri, C.I. (eds.), *Spatial Information Theory: A Theoretical Basis for GIS*. Berlin: Springer Verlag: 377-390.

DAESSLER, R. and PALM, H., 1998. *Virtuelle Informationsräume mit VRML*, Heiderlberg: dpunkt verlag.

ELIAS, N., 1969. Die höfische Gesellschaft. Untersuchungen zur Soziologie des Königtums und der höfischen Aristokratie, Neuwied und Berlin: Luchterhand.

ELIAS, N., 1987. *Über die Zeit. Arbeiten zur Wissensoziologie II*, Frankfurt am Main: Suhrkamp.

FISHWICK, P.A., 1996. *Extending Object-Oriented Design for Physical Modelling*, University of Florida (ftp://ftp.cis.ufl.edu/cis/tech-reports/tr96/tr96- 026.ps).

FOLTZ, M.A., 1998. *Designing Navigable Information Spaces*, St. Louis: Washington University (http://www.infoarch.ai.mit.edu/publications/mfoltz-thesis/; http://www.infoarch.ai.mit.edu/jair/jair-rationale.html).

FRANK, A.U. and CAMPARI, I. (eds.), 1993. Spatial Information Theory, Springer-Verlag, Berlin. In Helfrich, H. (ed.), 1996, *Time and mind*. Seattle: Hogrefe & Huber Publishers.

HOLLERBACH, J.M., 1975. *Hierarchical Shape Description of Objects by Selection and Modification of Prototypes*, MIT Artificial Intelligence Laboratory Technical Report 346.

HOTTA, K., 1992. Systematization of Displays. In Museum and Amusement Parks, *Display Designs in Japan*, 4: 16-35. Tokyo: Rikuyo-sha Publishing.

JENSEN, J., 1993. Christian Jörgensen Thomsen's Museum - a Vision of the Golden Age, *Nordisk Museologi*, 1: 17-30.

KOSSLYN, S., 1981. The medium and the message in mental imagery: A theory, *Psychological Review* 88: 46-66.

LEVINSON, S., 1998, Studying spatial conceptualizations across cultures. *Anthropology and cognitive science*. Ethos, 26: 7-24.

McNAMARA, T., 1986. Mental representation of spatial relations. *Cognitive Psychology* 18: 87-121.

O'NEILL, R. and MUIR, E., 1998. *Web developer.com guide to create 3D worlds*. New York: Wiley Computer Publishing.

PEDERSEN, B.M, 1988. *The Graphic Visualization of Quantitative Information, Procedures and Data*. Zurich: Graphis Press.

RETZ-SCHMIDT, G., 1988. Various Views on Spatial Prepositions, *AI Magazine* 6: 95-105.

SEARLE, R.J., 1958, Proper Names, *Mind* 67: 166-173.

STECKNER, C., 1993. Zum Verbund kommunikativer Lagebeziehungen. In Petzold, L., Schneider, I. and Streng, P. (eds.), *Bild und Text*, 202-209. Bratislava: Slovak Academic Press.

STECKNER, C., 1994. Museen im Zeichen der Französischen Revolution: vom evulutionären zum revolutionären Museum. In Grote A. (ed.), *Macrocosmos in Microcosmo*: 817-853, Opladen: Leske + Budrich.

STECKNER, C., 1995. SAMOS: Automatic Classification of Ancient Greek Pottery According to the Shape. In Nissan, E. and Schmidt, K. (eds.), *From information to knowledge: conceptual and content analysis by computer*, 126-150. Society of Conceptual and Content Analysis by Computer: Concepts - Content - Meaning 1, Oxford: Intellect books.

STECKNER, C.A., 1999. Anticipatorial Maps, *International Journal of Computing Anticipatory Systems* 4: 101-124.

STECKNER, C., 1999. Cross-modal visual transfer and the forming of haptic anticipatory phantom objects. In Bülthoff, H.H. and Fahle, M. (eds.), *Beiträge zur 2. Tübinger Wahrnehmungskonferenz* 100, Kirchentellinsfurt: Knirsch Verlag.

STECKNER, C., 2000. Form and Fabric. In Barceló, J.A., Forte, M., Sanders, D.H. (eds.), *Virtual Reality in Archaeology*: 121-128. Stafford: BAR International Series 843.

THOMAS, C., 1996. *To Assist the User: On the Embedding of Adaptive and Agent-based Mechanisms*. Munich: Oldenbourg-Verlag (GMD-Bericht Nr.258).

THORNDYKE, P.W. and HAYES-ROTH, B., 1982. Differences in spatial knowledge acquired from maps and navigation. *Cognitive Psychology* 14: 560-589.

TUFTE, E.R., 1990. *Envisioning Information*, Chesire, CT: Graphics Press.

WAGENER-WENDER, M., 1993. *Mentale Repräsentationen räumlicher Informationen*. Bonn: Holos.

YIP, K. and ZHAO, F., 1996. Spatial Aggregation: Theory and Applications, *Journal of Artificial Intelligence Research* 5: 1-62.