MITSUBISHI ELECTRIC RESEARCH LABORATORIES
http://www.merl.com

Mapping Psychological and Virtual Spaces

Carol Strohecker

TR98-12 December 1998

Abstract

ẄayMakerïs a tool enabling non-professionals to create digital layouts for large-scale graphical virtual environments. The design tool is based on ëlements of the city imageäs described by the urban planner, Kevin Lynch (1960). Ultimately, WayMaker should be situated within a virtual environment so that output from the tool is transformed as extensions to the virtual world. Here we describe an initial prototype that simulates a virtual domain through a series of composited frames. Our work with users informs continued development of the tool. We also plan usage studies conducted from a cognitive science perspective, examining issues of constructive learning and spatial cognition.

Online Proceedings of Design Computing on the Net, sponsored by the International Journal of Design Computing, 1998

MERL - A MITSUBISHI ELECTRIC RESEARCH LABORATORY

Mapping Psychological and Virtual Spaces

Carol Strohecker
MERL - A Mitsubishi Electric Research Laboratory,
Cambridge, Massachusetts

Barbara Barros
MIT Department of Urban Studies and Planning;
StrataVarious Software, Boston, Massachusetts

Adrienne Slaughter
MERL - A Mitsubishi Electric Research Laboratory;
Massachusetts Institute of Technology

TR98-12 September 1998

Published in Design Computing on the Net '98, *International Journal of Design Computing*, 1998.

Abstract

"WayMaker" is a tool enabling non-professionals to create digital layouts for large-scale graphical virtual environments. The design tool is based on "elements of the city image" as described by the urban planner, Kevin Lynch (1960). Ultimately, WayMaker should be situated within a virtual environment so that output from the tool is transformed as extensions to the virtual world. Here we describe an initial prototype that simulates a virtual domain through a series of composited frames. Our work with users informs continued development of the tool. We also plan usage studies conducted from a cognitive science perspective, examining issues of constructive learning and spatial cognition.

Long ago the urban theorist Kevin Lynch pointed out the fundamental relationship between human cognition and urban form — the importance of the learned mental maps that knowledgeable locals carry about inside their skulls. These mental maps, together with the landmarks and edges that provide orientation within the urban fabric, are what make a city seem familiar and comprehensible.

— (Mitchell, 1995, p.43)

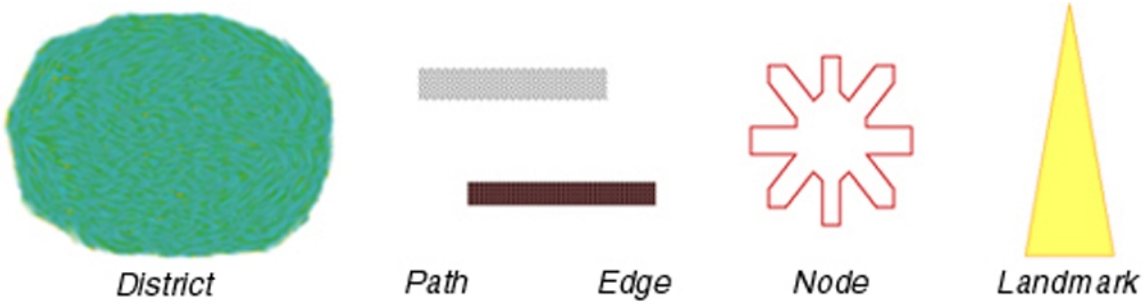
In *The Image of the City* (1960), Kevin Lynch describes how people "image" the city — that is, how they create and remember mental images of the large-scale environments in which they live. He focused on how people think about the structure of their cities. From verbal and pictorial accounts, he derived five basic elements of the city image: districts, paths, edges, nodes, and landmarks.

Although mental images are individualistic, Lynch found that people represent certain city elements consistently. Districts are broad regions, such as neighborhoods, that have some common, identifying character such as brick sidewalks or rows of brown-stone buildings. Paths are the channels along which people move; they may be narrow like sidewalks or wide like roads. Edges are distinct boundaries between one region and the next; they may function as barriers or seams. Nodes are strategic points, foci to and from which people travel. Landmarks are punctuation points used for general orientation; they may be distant or local.

Urban planners and designers recognize the usefulness of these elements not just in reflecting on the structure of the city, but also in creating it. Lynch's elements are insufficient to characterize the experience of an urban environment. However, professionals assume that a well-designed, "imageable" city incorporates the elements that Lynch articulated (Banerjee & Southworth, 1990; Lynch, 1981). Thus, by basing WayMaker on Lynch's elements, we are drawing from well-honed practice as well as addressing a current problem in virtual environment design: as virtual environments become more commonplace, a greater variety of people will be involved in developing them.

Participants in text-based multiuser environments like "MUDs" and "MOOs" typically interact with each other, but also with the environment. They use an associated programming language to construct characters, objects, and spaces within the virtual domain (Curtis, 1992; Rheingold, 1993; Bruckman & Resnick, 1995; Mitchell, 1995; Turkle, 1995; Bruckman, 1997). However, this constructive component is not easily transferred to graphical environments. The tools for developing images and structures tend to be complex and sophisticated, often requiring professional expertise in order to produce a satisfying result. Yet, graphical virtual environments are emerging as milieus with potential for broad use in learning, entertainment, and socializing (Benedikt, 1991; Anderson et al., 1995; Shaw, 1995; Darken, 1996; Darken, & Sibert, 1996; Moshell & Hughes, 1996; Strohecker, 1997; Strohecker & Barros, 1997). Clearly we need to develop easily usable tools to support participants' interactions, including world construction, navigating, and wayfinding.

WayMaker users work directly with representations of Lynch's elements. Each symbol corresponds to an aspect of city form. The five basic symbols represent districts, paths, edges, nodes, and landmarks.



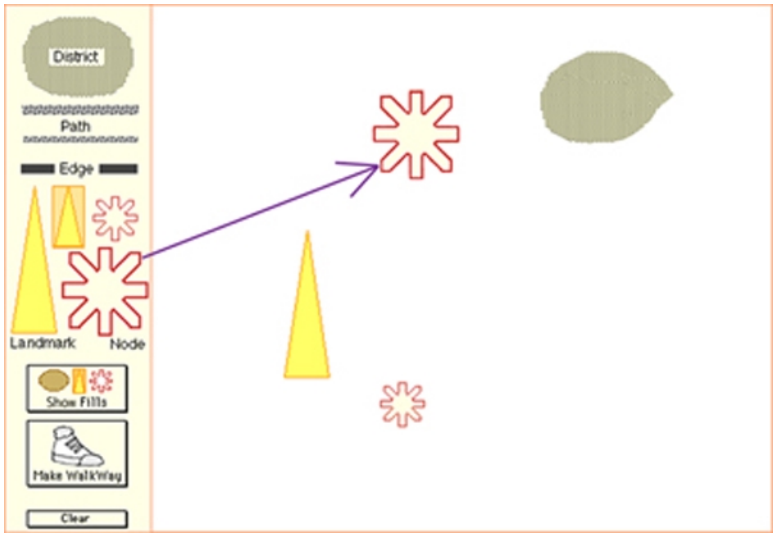
Placing the symbols to develop a map-like diagram, the user assumes a bird's-eye view and imagines the virtual domain at large scale. The user can modify the symbols to specify details such as the visual character of districts and landmarks. In the illustration below, WayMaker's pictorial vocabulary indicates relative placements and sensory attributes of three elements within a district. A triangle becomes a landmark representing a memorable building, and an edge demarcates the end of the observer's path. The software transforms the user's design into street-level scenes representing a walk through the domain. For the initial prototype we worked with reproductions of paintings by Paul Cézanne to form the street-level scenes.

Painting and photograph excerpts from Machotka (1996). Painting: Ferme à Montgeroult, 1898.

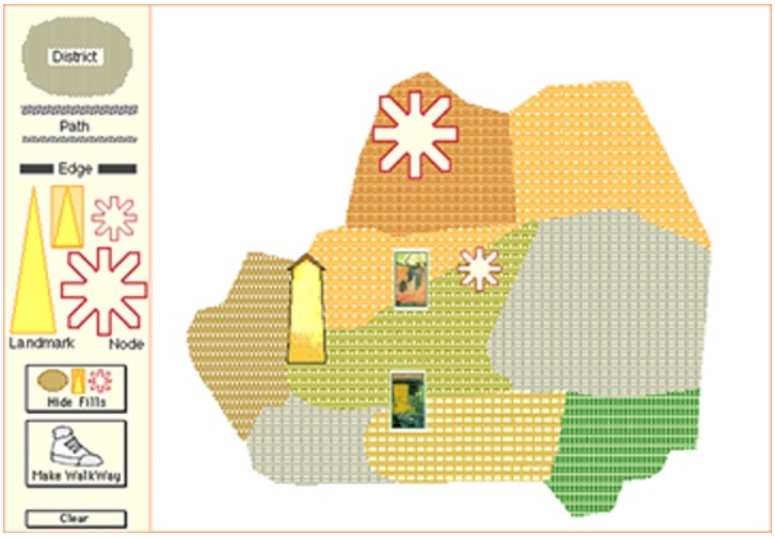
Lynch's elements can be found in the context of city renditions such as those by Cézanne. Many of his works comprise studies of the relationship of the built to the natural environment. His impressionistic imagery lends itself to our technique of compositing simulated views through a virtual domain.

Painting reproduction from Machotka, P. (1996): Gardanne (l'après-midi), 1885-86.

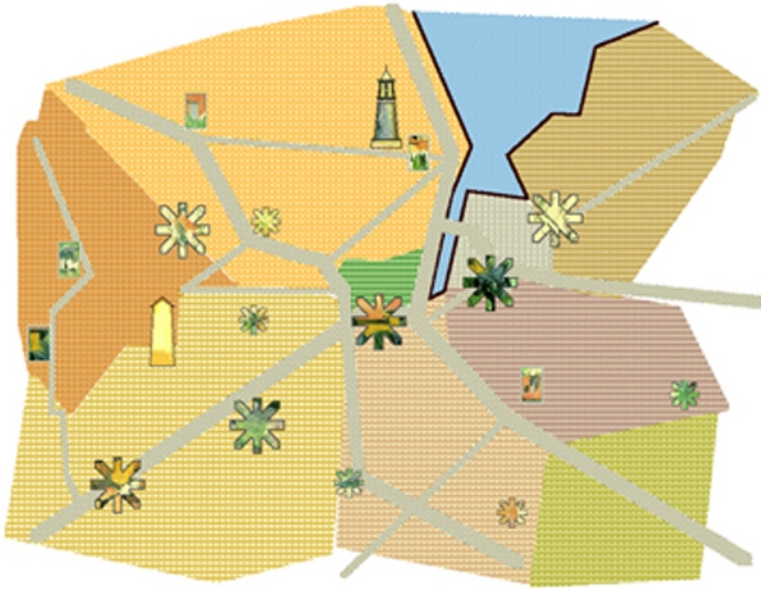
To begin designing an image of the virtual space, the user simply drags symbols into the working area.



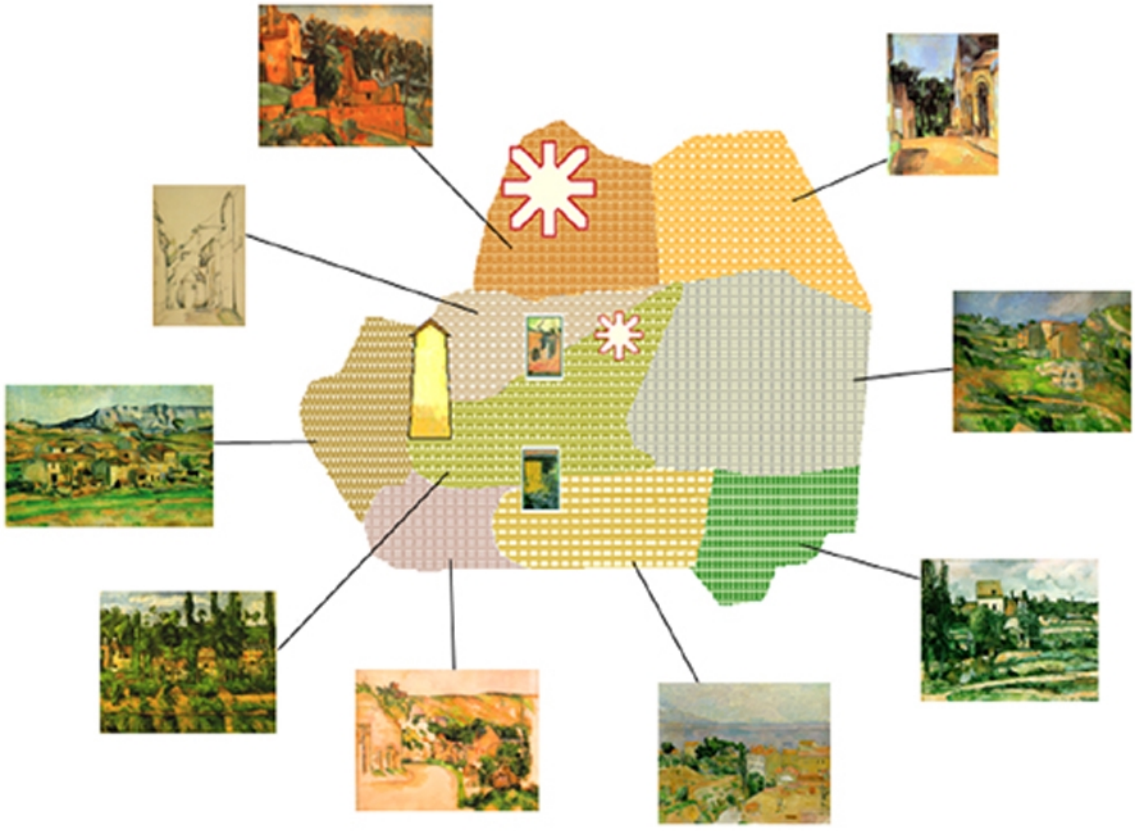
District, edge, and path symbols can be stretched and curved to assume various shapes. Nodes and landmarks can be placed anywhere in the diagram as elements to be encountered along the walkways.



This fully developed layout includes all five elements placed relative to one another. Menu specifications for nodes, landmarks, and districts fill the corresponding symbol with an indication of imagery the software will use in the final walkway sequence. Paths, landmarks, and nodes are available in two sizes: a path may function as boulevard or alley; large landmarks can appear as towers; small landmarks can become smaller buildings or banners marking points of interest.

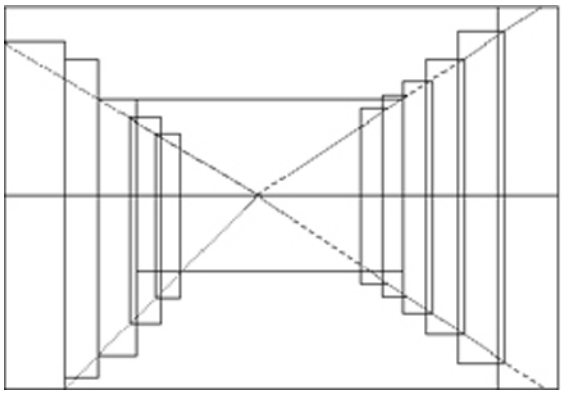


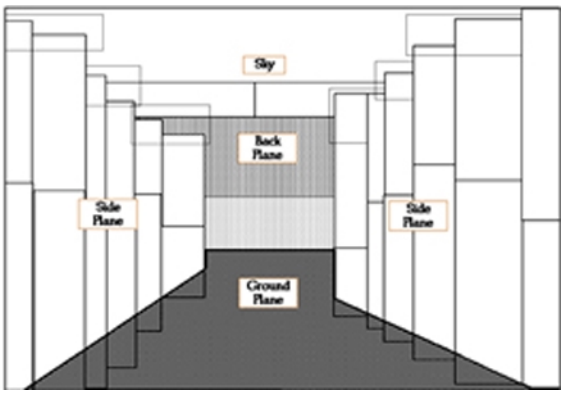
Users can select from reproductions of the Cézanne paintings in order to specify the character of a given district. For the walkthrough, the software uses excerpts from the paintings in automatic compositions of street-level scenes.



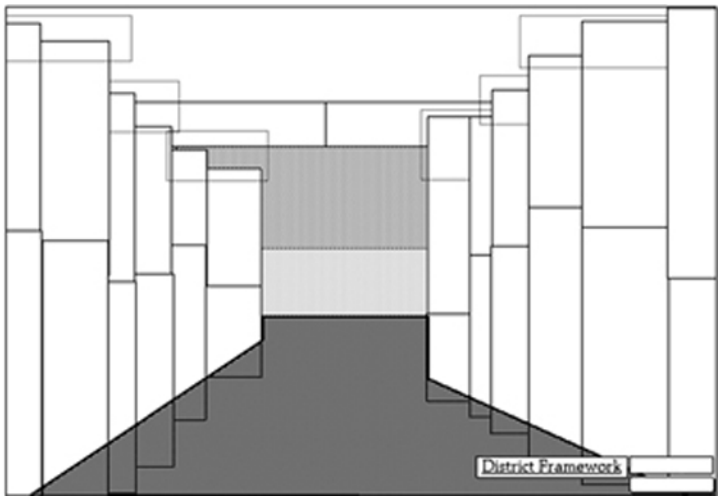
Painting reproductions are from Machotka, P. (1996). Clockwise, from top right: Ferme à Montgeroult, 1898; Maisons en Provence – le vallon de Riaux près de l'Estaque, 1882-83; Le Moulin sur la Couleuvre à Pontoise, 1881; Les Marrioniers du Jas de Bouffan en hiver, 1885-86; Route tournante à la Roche-Guyon, 1885; Le Château de Médan, 1879-80; Haneau à Payennet près Gardanne (formerly La Sainte-Victoire, Environs de Gardanne), 1885-86; L'Eglise Saint-Pierre à Avon (formerly Une rue à Aix), 1891-92; La Maison de Bellevue, c. 1890.

The classic perspectivist framework consists of a ground, sky, and side planes, which are defined by diagonals that converge on a vanishing point along the horizon in the back plane. We use this framework as the basis for automatic compositions of street-level views. Each scene in a walkthrough of the virtual domain is comprised of side planes, ground, back, and sky. Added detail helps to ensure variety: silhouetted images crown the back plane, and side planes may consist of bases, facades, and/or roofs.



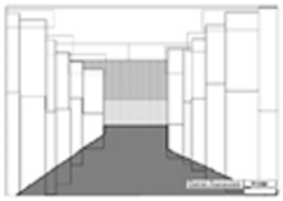


Cézanne's Ferme à Montgeroult presents a scene with a certain structural character: the terrain is smooth and relatively flat; each side of the street is covered evenly with buildings; building facades often have distinguishable bases and rooftops. We incorporated these observations into a framework that characterizes Cézanne's scene and WayMaker districts associated with it. Each component is represented as a set of variable coordinates to be filled with an appropriate excerpt from the painting.

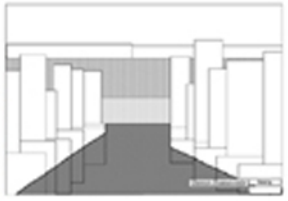


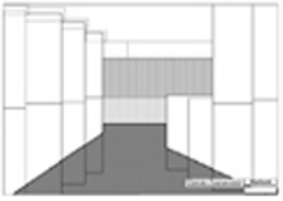
To generate variety within each district, we established ranges within which the number and measure of scene components can change. These ranges are consistent with the character of the associated painting. WayMaker automatically composes walkway scenes by placing image excerpts within such variations of the district's structural framework.

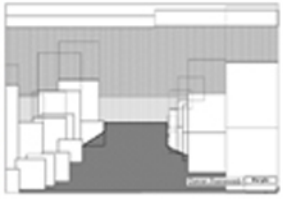
Variation also occurs from district to district, as the composition of side panels changes. The number and measure of bases, facades, and roofs are peculiar to each district. Each painting's framework suggests certain relationships: side to side, roof to facade, facade to base, base to ground, back to ground, etc. Differences in these relationships contribute to the richness of WayMaker's simulated virtual worlds.

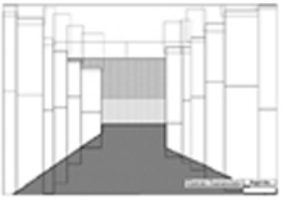



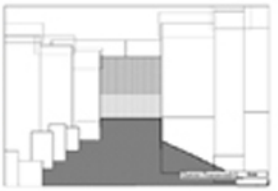






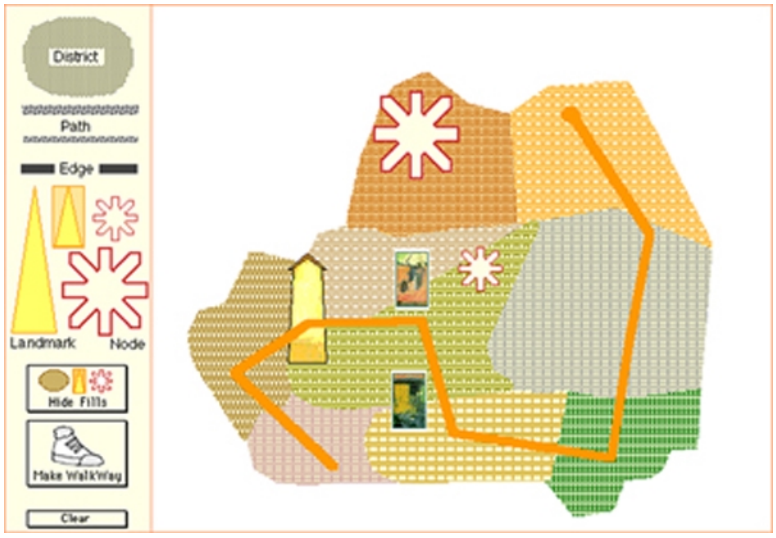




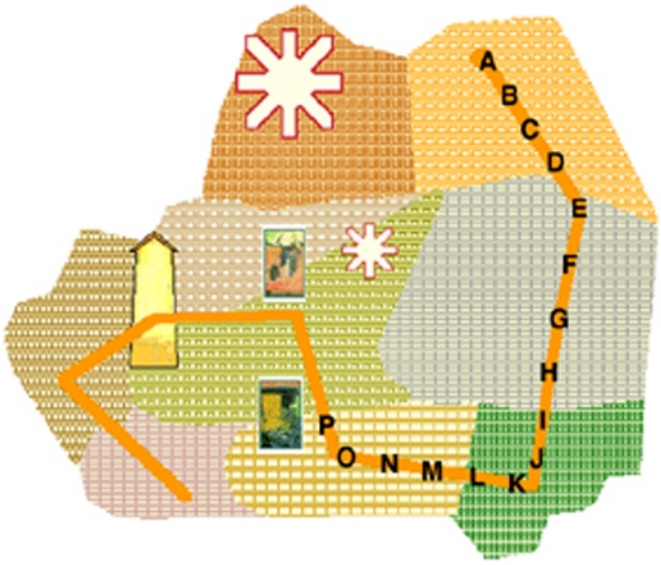


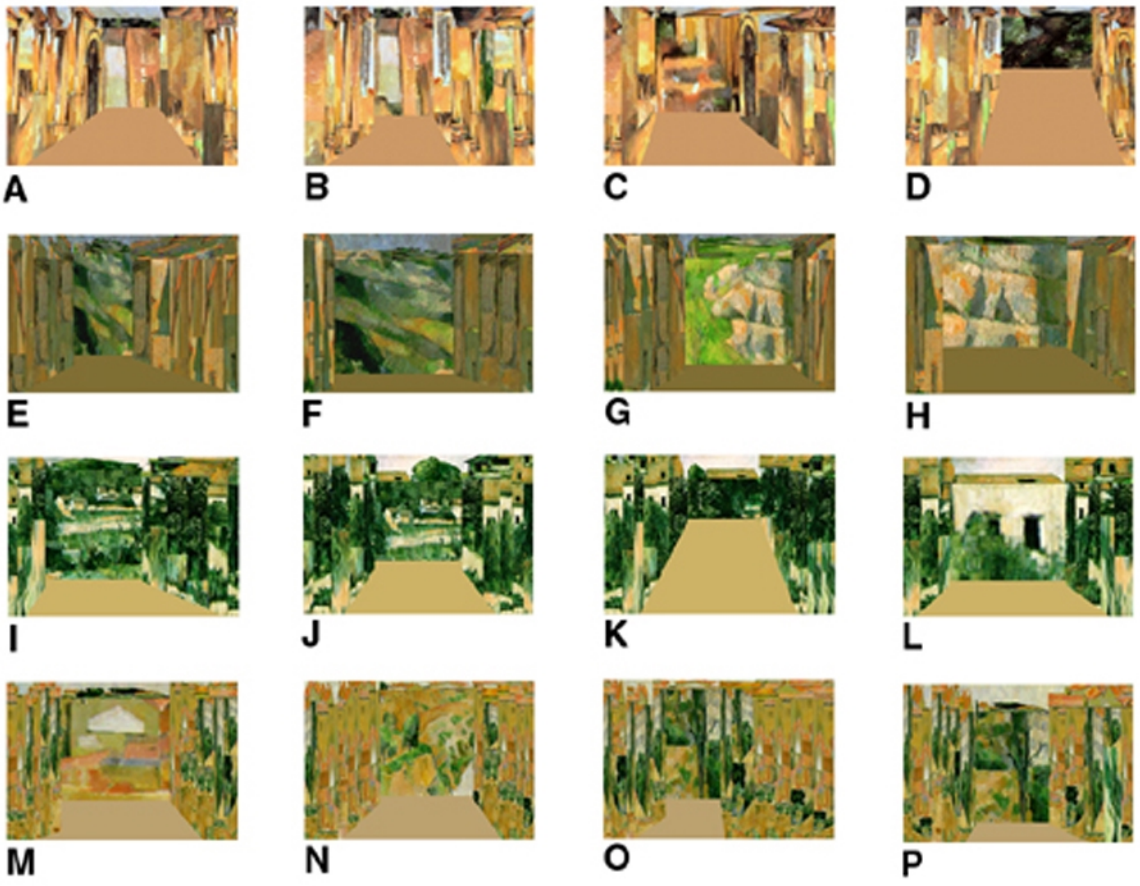


When the user has finished specifying details of the layout, s/he can click the sneaker icon to change modes and indicate a walkway route through the environment.



The user clicks the tip of the walkway ribbon to trigger calculation, assemblage, and display of a corresponding sequence of street-level scenes. The software ascertains which district the walkway is traversing, selects the appropriate framework, draws from the associated database of images in order to fit components into corresponding parts of the framework, varies the framework and again fills it with image components, and continues this process to the end of the walkway. The result is a series of scenes in a simulated virtual world.


A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P


A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P

Thus the user-designed map undergoes three transformations. The representation changes from a diagram composed of abstract symbols to recognizable, though impressionistic, imagery. The view changes from bird's-eye to street-level. The scale changes from that of a city, town, or region to that of a human stroll.

Further Work

We believe that the best way to support users in appreciating these transformations is to provide simultaneous displays of the map and the walkthrough scenes (c.f. Brooks, 1986). In our continued development of the prototype, we are changing the display so that it indicates each scene's location within the diagram as the walkway sequence plays out. This double display should emphasize the connection between user-created diagrams and the constructed virtual world. We are also developing a new approach that will eliminate the step of adding the walkway ribbon, and enable users to follow in the walkthrough the same paths they have placed in creating their diagrams. Other improvements include refined placement of nodes and landmarks within the views, and the addition of bursts of sounds and images to suggest human activity associated with nodes.

WayMaker diagrams could be associated with any number of prepared databases, yielding any number of apparent worlds. We have implemented the prototype on a personal computer and are using two-dimensional imagery for both the construction kit and the walkthrough sequences. WayMaker could easily use alternate 2D databases for the walkthrough scenes. For example, we could develop image databases from Picasso paintings or sets of photographs instead of the Cézanne imagery. Furthermore, with appropriate development, the information in the maps could be translated as 3D arrangements of the structural elements. Again, the relative placements of the elements are key point; images representing the elements in the walkthrough are interchangeable. Thus the current depictions of scenes in a WayMaker virtual space are independent of the question of whether or how Lynch's formulations may be broadly useful as a basis for design and construction tools for virtual worlds.

We expect users' experiences with WayMaker to inform our understanding of how people think about and organize virtual space, what kinds of virtual places they would like to "inhabit," and ways in which manifestations of Lynch's elements could become useful, feasible additions to the repertoire of tools for graphical multiuser environments. Some of the data should be interesting from a cognitive science perspective as well. The interaction technique of constructing representations of an environment is based on theories of spatial cognition focusing on knowledge creation rather than knowledge acquisition (Gruber & Vonèche, 1977; Harel & Papert, 1991; Papert, 1980; Piaget, 1951/1929, 1970/1946; Piaget & Inhelder, 1967). The "constructionist" design will support studies of individual differences from a developmental perspective.

Researchers in spatial cognition focus on two kinds of conceptual growth: "development of fundamental concepts of space, and the further differentiation and elaboration of these

concepts into the development and representation of large-scale environments" (Hart & Moore, 1973, p. 248). The developmental psychologist and genetic epistemologist Jean Piaget was concerned with growth of fundamental concepts; the urban planner and designer Kevin Lynch was concerned with their application and nurturance in large spaces. Although these researchers worked at different scales and in different domains, they shared an interest in how individuals' conceptions of space grow through interactions with the physical environment (Piaget & Inhelder, 1967; Lynch, 1960). WayMaker can support studies of cognitive development from both perspectives. We hypothesize that this combination may yield results in an apparently different but deeply related domain: Lynch's elements are essentially topological. In using them to plan the structure of virtual places, users may deepen their understandings of this type of mathematical relationship as well as improving spatial skills such as orientation and navigation (Beth & Piaget, 1966; Papert, 1980; Strohecker, 1991).

Acknowledgments

Painting reproductions are from (Machotka, 1996). Work related to WayMaker is supported by MERL - A Mitsubishi Electric Research Laboratory, in Cambridge, Massachusetts. We are grateful to MERL staff members, and to students and staff of the Graduate School of Design, Harvard University, who experimented with the initial prototype and provided usage data that will help guide development of subsequent versions: Nadir Ait-Laoussine, Larry Burks, Jutiki Twan Gunter, Surapong Lertsithichai, Pau Sola-Morales, and Mark Strehlow. Contributors to the next version include Maribeth Back (XeroxPARC) and Daniel Gilman (Massachusetts College of Art).

References

Anderson, D. B., Barrus, J. W., Howard, J. H., Rich, C., Shen, C., & Waters, R. (1995). Building multi-user interactive multimedia environments at MERL. IEEE MultiMedia 2(4), 77—82.

Banerjee, T., & Southworth, M., eds. (1990). City sense and city design: Writings and projects of Kevin Lynch. Cambridge, MA: MIT Press.

Benedikt, M., ed. (1991). Cyberspace: First steps. Cambridge, MA: MIT Press. Beth, E. W., & Piaget, J. (1966). Mathematical Epistemology and Psychology. Trans. Mays, W. Dordrecht-Holland, D. Reidel.

Brooks, F. P., Jr. (1986). Walkthrough ‹ A dynamic graphics system for simulating virtual buildings. Proceedings of the 1986 workshop on interactive 3D graphics. Chapel Hill.

Bruckman, A. (1997). MOOSE Crossing: Construction, Community, and Learning in a Networked Virtual World for Kids. Massachusetts Institute of Technology, Media Laboratory; Doctoral dissertation.

Bruckman, A., & Resnick, M. (1995). The MediaMOO project: Constructionism and professional community. Convergence 1:1.

Curtis, P. (1992). Mudding: Social phenomena in text-based virtual realities. Proceedings of the 1992 conference on directions and implications of advanced computing. Berkeley. (Technical Report CSL—92—4, via anonymous ftp: ftp://parcftp.xerox.com/pub/MOO/papers/DIAC92.*). Palo Alto: Xerox PARC.

Darken, R. P. (1996). Wayfinding in large-scale virtual worlds. George Washington University, Department of Electrical Engineering and Computer Science; Doctoral.dissertation.

Darken, R. P., & Sibert, J. L. (1996). Wayfinding strategies and behaviors in large virtual worlds. Proceedings of ACM special interest group on computer-human interaction.

Gruber, H. E., & Vonèche, J. J., eds. (1977). The Essential Piaget. New York: Basic Books.

Harel, I., & Papert, S., eds. (1991). Constructionism. Norwood: Ablex.

Hart, R. A., & Moore, G. T. (1973). The development of spatial cognition: A review. In Stea, B., & Downs, R. (eds.) In Image and environment, pp.226—234. Chicago: University of Chicago Press.

Ingram, R., & Benford, S. Legibility enhancement for information visualisation. Visualization'95 Proceedings. Los Alamitos, CA: IEEE Computer Society Press.

Janson, H. W. (1962). History of art: A survey of the major visual arts from the dawn of history to the present day. Englewood Cliffs; New York: Prentice-Hall; Abrams.

Lynch, Kevin. (1960). The image of the city. Cambridge: MIT Press.

Lynch, Kevin. (1981). Good city form. Cambridge: MIT Press.

Machotka, P. (1996). Cézanne: Landscape into art. New Haven: Yale University Press.

Mitchell, W. J. (1995). City of bits: Space, place, and the Infobahn. Cambridge, MA: MIT Press.

Moshell, J. M., & Hughes, C. E. (1996). The virtual academy: A simulated environment for constructionist learning. International journal of human-computer interaction.

Oles, P. S. (1988.) Drawing the future: A decade of architecture in perspective drawings. New York: Van Nostrand Reinhold.

Papert, S. (1980). Mindstorms: Children, computers, and powerful ideas. New York: Basic Books.

Piaget, J. 1951 [1929]. The child's conception of the world. Tomlinson, J. & Tomlinson, A., trans. New York: Humanities Press.

Piaget, J. 1970 [1946]. The child's conception of movement and speed. Holloway, G.E.T., & Mackenzie, M. J., trans. New York: Basic Books.

Piaget, J., & Inhelder, B. (1967). The child's conception of space. Trans. Langdon, F. J., & Lunzer, J. L., New York: W. W. Norton.

Rheingold, H. (1993). The virtual community: Homesteading on the electronic frontier. Reading: Addison-Wesley.

Shaw, A. (1995). Social Constructionism and the Inner City: Designing Environments for Social Development and Urban Renewal. Massachusetts Institute of Technology, Media Laboratory; Doctoral dissertation.

Strohecker, C. (1991). Why Knot? Massachusetts Institute of Technology, Media Laboratory; Doctoral dissertation.

Strohecker, C. (1997). The "Zircus" concept sketch for a learning environment and online community. Presence 6:3.

Strohecker, C., & Barros, B. (1997). A Prototype Design Tool for Participants in Graphical Multiuser Environments. Extended abstracts, CHI'97: Looking to the future, Conference on human factors in computing systems.

Turkle, S. (1995). Life on the screen: Identity in the age of the Internet. New York: Simon & Schuster.