Image Maps: Exploring Urban History through Digital Photography

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Abstract. This paper describes an integration of geographic information systems (GIS) and multimedia technologies to create opportunities for people to explore the history of their cities. We have augmented a digital camera with a global positioning system (GPS) and a digital compass to record its position and orientation when ordinary photographs are taken. The metadata are used to retrieve and present historical images of the photographed locations to photographers. Another set of tools allows students to annotate and compare these historical images to develop explanations of how and why their communities have changed over time. We describe the hardware and software architectures and learning outcomes that we expect to see in classroom use.

1 Introduction

We think of cities as places where we live, work, and play, but there is also a great deal that we can learn from them. The city is a "laboratory", a place where we can reflect on the successes and failures of architectural design and building [6]. Typically, we do not think of cities as learning environments, and we certainly do not see much emphasis placed on studying cities in most formal, school curricula. In this paper, we discuss ways for high school students to begin exploring their communities, to learn about how and why their cities have changed over time.

In the past decade, reform efforts in science education have suggested that students engage in authentic inquiry around scientific principles [1, 12]. That is, we should be giving students conceptual and technological tools to help students develop their own questions and strategies for testing and evaluating hypotheses. The thought is that learning is best facilitated when students conduct self-directed inquiry. Rather than giving them "cookbook" laboratory exercises, we should help them understand how to choose interesting research problems and conduct investigations to verify their hypotheses about these problems.

These reform ideas are not unique to science learning. We can imagine students doing similar investigation tasks in the streets of their cities. In most K-12 classrooms, subjects like history are presented through textbooks and other writings. In general, students are not given opportunities to explore historical issues in their own communities. They may take field trips to see local sites of interest, but they rarely

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use such journeys to investigate how and why their communities have changed over time.

We see opportunities for students to generate their own explanations of historical trends by engaging in "field work" in their cities. This fieldwork is complemented with digitized, archival photographs. Historical photographs provide a glimpse at the architectural, fashion, transport, and cultural trends of a period. By looking at a collection over time, students can reflect on how these trends change over time and their effects on cities. By integrating historical images with geographic information systems (GIS), students can look for spatial patterns and relationships that may vary geographically. For instance, noticing changes in transport throughout the city may give important clues to economic factors affecting city growth.

Rather than just giving students photographs with explanatory captions and narratives, we have developed a software suite, called *Image Maps*, allowing learners to annotate and compare historical images and to detect and explain patterns and relations over time. In this way, we hope to help them become better observers and critics of the real world through the use of imagery as data. To facilitate student inquiry, we have augmented a digital camera with a global positioning system (GPS) and a digital compass to record position and orientation metadata when pictures are taken. When the camera is downloaded, each augmented picture is used to retrieve historical pictures of the photographed location using image and GIS databases. By integrating GIS data with multimedia objects [7, 15], student photographs can be geo-referenced, providing additional data for inquiry. More importantly, students' images of the present are connected to those of the past, providing the basis for inquiries into community change.

2 Learning in the City

The premise of this research is that students can learn critical observation and interpretation skills by investigating changes in their local communities. Many authors describe the changes in urban landscapes [5, 6, 8] while others describe the details of developing organized arrangements for city planning [2, 3, 9]. Such texts provide ways for us to begin thinking about learning from our cities, but they do not actively engage students in conducting the process for themselves. There is much to be learned from becoming an active explorer of one's city [16], and our goal is to assist students in realizing that they can conduct investigations in their neighborhood "laboratories".

Because we do not typically think of cities as places where we can learn, we have to develop supports and strategies to help students proceed in their exploration. In other words, we have to create a methodology for students to use in their daily walks from home to school, a task structure to help them become careful observers and interpreters of the nuances of the city. To do this, we provide students with a set of tools for thinking about city change.

2.1 Learning with Images

Photographs play a large role in this work, providing students with historical evidence to compare against the current city. With photographs, we can see parts of the city fabric that no longer exist, other parts that have been modified or transformed, and still others that are no longer recognizable today. A city like Los Angeles, for instance, once had vast rail services that linked the suburbs to the city center [8]. Today, these rail lines can only be seen in pre-World War II photographs. Within these historical images lies history, a sense of what it was like to live in a city. A bit of introspection can help learners think about why features of the city were transformed or destroyed to make way for new innovations.

Urban planners use historical imagery to study the aesthetics and functionality of city environments [3, 19]. Patterns of urban change can be difficult to explain or justify without using qualitative data such as photographs. Time lapse photography and documenting changes with sequences of photographs are two techniques that allow for analysis of city transformations and communicating hypotheses. We want students to engage on similar strategies. They will use historical photographs to construct temporal chains of evidence to support theories of how and why their cities have changed over time.

We go beyond simply providing images by registering the members of the historical archives to their appropriate geographical locations. By associating the buildings in these photographs with GPS data, students can search on a location to see how features of that location have changed. This may mean that a building has grown or diminished over time. In many cases, students will poll a location only to find buildings that do not exist today. For instance, MIT's famed Building 20 was recently destroyed to make way for a new computer science building; in five years, students going to that location will only be aware of Building 20 through photographs. The images provide evidence for patterns that existed in the past. By geo-referencing these images, they become more connected to specific locations, allowing students to conduct focused inquiry around spatial patterns in their cities.

2.2 Learning by Designing Pattern Languages

In the 1970's, Christopher Alexander and his colleagues introduced the concept of pattern languages to the architectural community [2]. The elements of the pattern language are schemata describing frequently occurring problems in man-made environments and solutions addressing the problem. In the original notation, each pattern begins with photograph displaying a prototypical example of the problem. Accompanying the image is a full description of the problem and evidence for it being a pattern that frequently occurs in architecture. A series of instructions to correct the problem accompanies the pattern, as seen in this description from the "Six-Foot Balcony" pattern:

> Balconies and porches which are less than six feet deep are hardly ever used…Therefore, whenever you build a balcony, a porch, a gallery, or a terrace, make it at least six feet deep. If possible, recess at least part of it

> into the building so that it is cantilevered out and separated from the building by a simple line, and enclose it partially [2, pp. 783-784].

These patterns were originally intended for practicing architects and urban planners, but they can be adapted for our purposes of educating K-12 students. One can imagine students using these patterns and instructions to analyze their cities, to develop and understanding for what elements of their communities work and fail with respect to Alexander's pattern language. However, students may gain more by doing the same exercise that Alexander and his colleagues did in formulating the original pattern language. Rather than simply drawing relations between city features and the existing pattern language, we would like students to create their own catalog of design patterns. These student-generated patterns would be created as they travel through their communities and explore historical photographs looking for examples of regularity and variation is architectural features.

To create these patterns, students must annotate images with relevant features that form the basis for describing relationships between parts. The juxtaposition of urban characteristics determine the look and feel of urban space [3], and simple features such as building materials, the heights of traffic lights, and sidewalk layouts can tell us important things about the evolution of a city. By annotating features of the image library with these traits, students can begin to see spatial patterns emerging, patterns that suggest property lines, zoning regulations, and public/private boundaries. When traced over time, these boundaries can provide insights into the complexities of the urban environment's growth.

So we want students to go out into their communities and become explorers and investigators. To help them with their journey, we provide them with an additional source of data to work with, a collection of historical images that can be accessed by their spatial location. These images provide the foundations for developing arguments about how and why a city has changed. In order to organize these arguments, we introduce students to pattern languages as a way to identify regularities and variations in the architectural features of their communities. The design of a pattern library becomes the end goal for the students; their task is to catalog relationships between cities. In a sense, they become urban planners, actively investigating their cities and developing theories about why their construction.

3 Retrieving Images with Images

To get a sense for the types of activities that we hope to see, we provide a hypothetical use scenario, a group of students on a field trip to Harvard Square. These students use our camera to take pictures of buildings and settings in this community that they like and dislike. After doing so, they return to their classroom and download their images into our software (Figure 1). The thumbnails on the right side of the display show students' photographs. When one of these thumbnails is placed into the crosshairs in the upper right, its enlarged image appears at right center, and a set of historical thumbnails matching the location of the selected image are displayed at the top — clicking one of these expands its image at the left center. Figure 1 shows how a

photograph of Harvard Square in 1999 retrieves many images of the same location between 1860 and 1980.

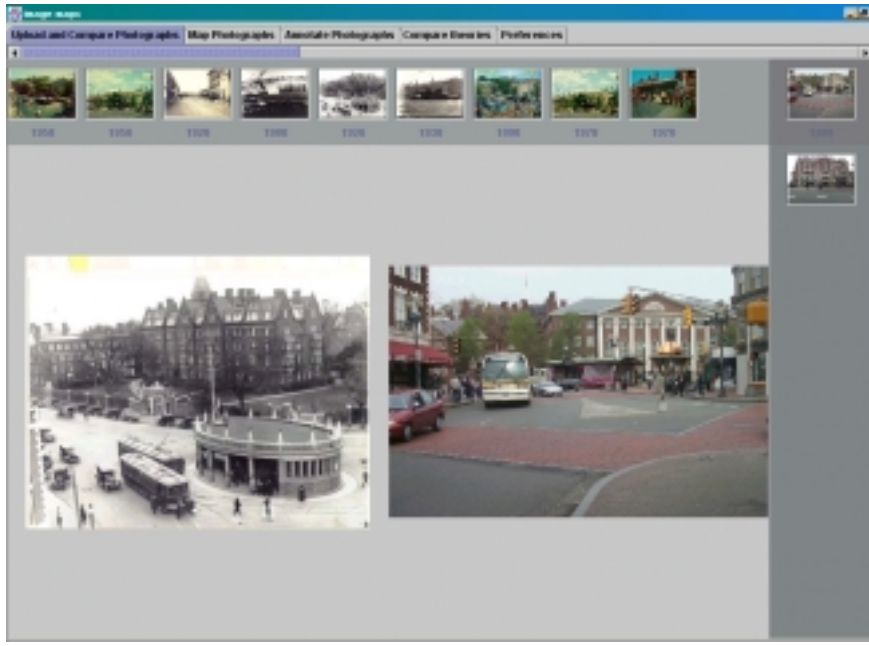

Fig. 1. The current retrieval interface. Thumbnails on the right are images taken by students. Choosing one of these displays its larger image and displays an array of historical thumbnails across the top. The left image is the historical photo chosen from the retrieved collection

The students now need to explain why they liked or disliked the objects and regions that they photographed. They do this by creating descriptive ontologies and labeling objects in the images with these features. For instance, Figure 2 shows a list of features that students might develop (*e.g.*, transport types, commercial buildings, road types, architectural features). The historical photos are tagged with these labels, and students can begin comparing images over time to see similarities and differences. As they mark up more photographs, they can begin to retrieve images using their ontological features and describe urban planning patterns [2] that have varied or remained consistent throughout history.

When students are taught to explore their outdoor surroundings, they can become more aware of the intricacies of man-made environments [16]. We assist this process by giving access to historical images that might otherwise go unseen by students. We claim that doing "field work" with our camera, obtaining a record of local history, and working to explain the various changes in the community can lead to new insights about historical, architectural, and social change.

We propose moving students out of the classroom building and into the city itself to study history in its natural setting. Observation and analysis in the field can yield

far more authentic results then possible within the classroom [16]. Rather than providing students with textbook explanations of history, we adopt a learner-centered approach [e.g., 14] to engage students in constructing and reflecting on their own explanations of image data. Previous work [11, 13, 18] has discussed the use of video as data in learning and coordinating complex tasks. We build on these projects by allowing students to acquire their own data in the form of photographs, and the annotation tools allow them to construct theories around issues in urban planning and cultural change.

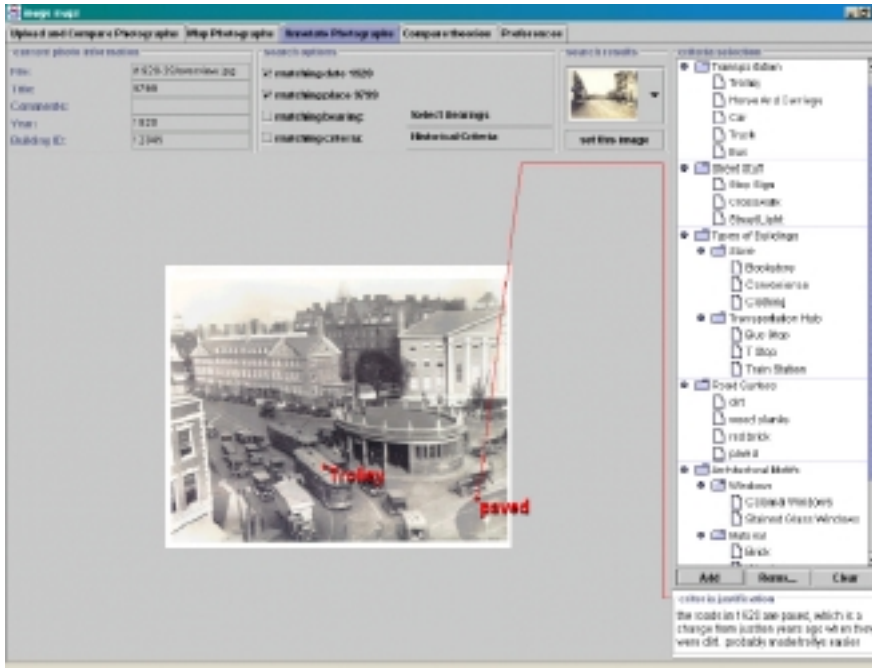

Fig. 2. Annotating images. Students develop ontologies to characterize interesting features of images. Objects in the photographs are labeled with these ontological features and used to develop explanations of community change

4 What Can You Learn From Image Data?

In the above scenario, there are a number of ways that students can learn with historical images provided by the camera. We are currently working to provide students opportunities to learn the following concepts:

1) *Observation and interpretation*. Rather than viewing images as "visual aids" to accompany textual explanations, students are responsible for drawing conclusions from image data. Comparing images across time periods can also provide insights into community change.

2) *Reasoning about urban planning.* We want students to develop hypotheses about the function of architectural structures. For instance, pedestrian crosswalks appeared rather recently in history. Students can pinpoint the time when they appeared and develop theories about why they may have been necessary. For instance, evidence of increased commercial buildings (*i.e.*, more commerce leads to more pedestrians) in the historical images may be correlated with the emergence of crosswalks.
3) *Reasoning about culture*. Images can provide important clues about community culture. For instance, a picture containing a "Buy War Bonds" advertisement is the beginning of a story about America during World War II. We hope to have students explore the meanings behind cultural artifacts found in images, possibly by collaborating with older adults to discover what is was like to live during the 1940's.
4) *Inquiry is an iterative process.* Although students could browse historical images without the camera, we feel that it is important for them to do "field work", to visit locations while constructing explanations of community change. In doing so, we hope they will better understand the iterative nature of inquiry, that returning to the field to make further observations will lead to new insights and questions.

Using GPS data to retrieve relevant historical information from a certain location has been proposed [10, 15], and this is one implementation of such a system. But instead of simply presenting historical synopses, our tools encourage students to build explanatory models using historical data. The “answers” to history are not returned by the system; one uses the primary documents retrieved by the system to build their own interpretations of historical change.

5 Technical Overview

A Kodak DC260 digital camera has been augmented with a Trimble Lassen-SK8 GPS and a Precision Navigation TCM2-80 digital compass. The camera uses Flashpoint Technology's Digita operating environment [4], allowing it to be scripted to send commands to the sensors through its serial port and to embed received data into JPEG images (Figure 3). In this way, the camera's origin and orientation are recorded when pictures are taken.

Our Java application parses the GPS and compass metadata from downloaded images and uses them to access a spatial map of Cambridge, Massachusetts stored in ESRI Inc.'s ArcView GIS. We start at the camera's origin (the point of image acquisition) and trace the orientation vector until we intersect a building or other landmark [17]. This raytracing routine approximates line of sight to return the name of the nearest landmark to the camera lens (Figure 4).

A separate Perl database associates each building name with a set of historical photographs. Each of these images has been hand-indexed with the position and orientation that it was taken from and the year when it was taken. The retrieval engine selects and displays images that closely match the view of the target image. If we cannot find images with similar shot distances and/or orientations, we relax the

constraints and return any photographs of the location. We currently test our retrieval algorithms with 1000+ hand-indexed images between Harvard Square and MIT.

Fig. 3. A segment of the ArcView GIS map for Cambridge, Massachusetts. The red dot shows the current camera position at a GPS coordinate. Orientation is used to trace a vector from the camera origin along its line of sight. The current algorithm simply returns the first building that intersects the line of sight vector

We are expanding our image database to provide students with richer data sources. The algorithm used to retrieve images is still rather simple, and we are developing a more sophisticated engine. For instance, the camera is recording tilt information at present, and we can use that data to disambiguate target buildings (*e.g.*, photographs of tall buildings with smaller ones in the foreground). We will also automatically add student photographs into the image collection to create image records of the present that can be used in future classrooms.

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6 Conclusion

Studying cities is rare in K-12 classrooms, and we are working towards a new class of visualization and modeling applications that use imagery as a primary data source for students to investigate their communities. Rather than simply reading historical

accounts, we want to see students arguing and debating about patterns of regularity and variation that can be found by exploring cities and comparing the present to the past. While most scientific visualization tools map quantitative data into visual representations, our students work directly with observational, image data, constructing qualitative models that can be used to predict future outcomes and events. The work described here is a first step towards fusing GIS and multimedia systems to produce new learning experiences through imagery.

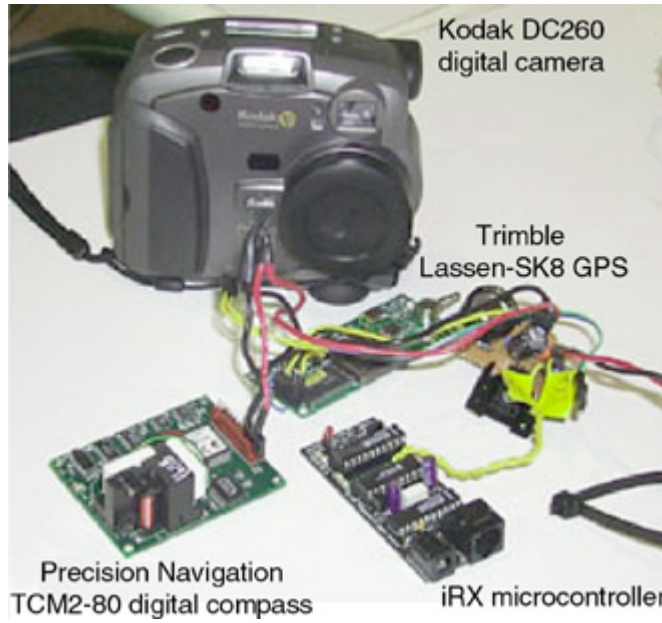

Fig. 4. An "out of the box" view of the camera hardware. A Kodak DC260 digital camera is attached to a Trimble Lassen SK-8 GPS and a Precision Navigation TCM-80 digital compass. This hardware configuration allows recording of position and orientation information into a JPEG image

One of our current concerns is the scalability of the project. Hand-indexing and registering historical images geographically consumes large amounts of effort. The best way to bring photographs into the system may be to allow our students to assist us in the indexing task. To do this, we created a web-based indexing tool (Figure 5) to allow users to contribute photographs to our database. Contributors select regions of the city that they want to add to and position a camera on screen to represent where the picture was taken and the approximate angle of view seen in the photograph. Our applet uses this information to create geographical metadata that can be used to retrieve the image in future searches, and the photo itself is added to our database.

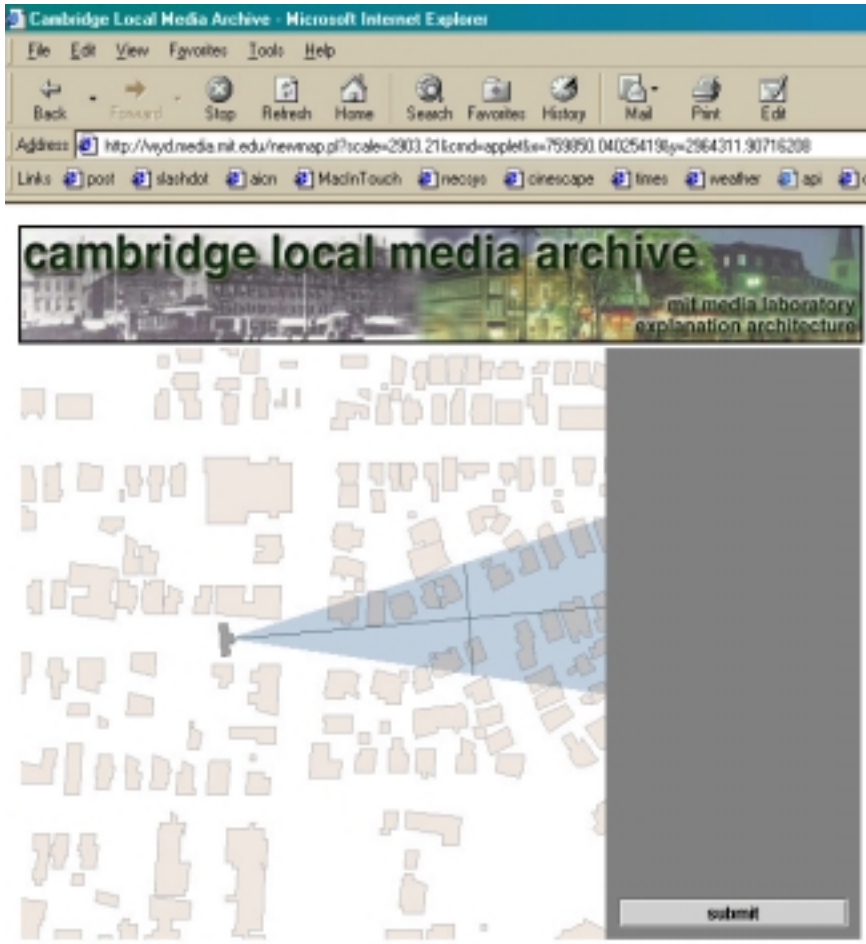

Fig 5. Auto-indexing images into the Image Maps database. Contributors align the graphical camera on the ArcView map at the position where a photograph was taken and adjust the "aperture" setting to show the area covered in the image. The applet uses this information to generate the geo-referenced metadata that accompanies the submitted image so future users of the system can retrieve it

We are hoping that this tool allows us to extend our database without the necessity for hand-indexing each photograph to a location. Also, by allowing people in the community to add to our databases, we hope to gain a much richer perspective on history. It is quite possible that the best historical, image archives are hidden in the photo albums of ordinary citizens, and the availability of this tool might help these images becomes available to a larger community.

Although we have tested the camera ourselves, our first deployment with children (14-16 years old) begins in late 1999. This initial deployment will inform the iterative design of the camera and software tools for constructing explanations about

community change. We will also attempt to understand the types of supports that teachers need to provide for this activity to successfully engage students in new ways of thinking about inquiry and their communities.

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References

1. American Association for the Advancement of Science: Science For All Americans: Project 2061. Oxford University Press, New York (1990)
2. Alexander, C., Ishikawa, S., Silverstein, M.: A Pattern Language: Towns, Buildings, Construction. Oxford University Press, Oxford (1977)
3. Bacon, E.N.: Design of Cities. Viking Press, New York (1967)
4. Flashpoint Technology: Digita Operating System: Script Reference. Flashpoint Technology, San Jose, CA (1998)
5. Hoskins, W.G.: The Making of the English Landscape. Penguin Books, Middlesex, England (1970)
6. Jacobs, J.: The Death and Life of Great American Cities. Vintage Books, New York (1992)
7. Kraak, M.-J.: Integrating multimedia in geographical information systems. IEEE Multimedia **3** (1996) 59-65
8. Kunstler, J.H.: The Geography of Nowhere: The Rise and Decline of America's Man-Made Landscapes. Touchstone, New York (1993)
9. Lynch, K. Hack, G.: Site Planning. The MIT Press, Cambridge, MA (1996)
10. Mitchell, W.J.: City of Bits. The MIT Press, Cambridge, MA (1996)
11. Nardi, B.A., Kuchinsky, A., Whittaker, S., Leichner, R., Schwarz, H.: Video-as-data: Technical and social aspects of a collaborative multimedia application. Computer Supported Collaborative Work **4** (1996) 73-100
12. National Research Council: National Science Education Standards. National Center for Education Statistics, Washington, DC (1996)
13. Smith, B.K. Reiser, B.J.: What should a wildebeest say? Interactive nature films for high school classrooms. In: ACM Multimedia 97 Proceedings, ACM Press, New York (1997) 193-201.
14. Soloway, E., Guzdial, M., Hay, K.E.: Learner-centered design: The challenge for HCI in the 21st century. interactions **1** (1994) 36-48
15. Spohrer, J.: Worldboard: What comes after the WWW? Available at http://www.worldboard.org/pub/spohrer/wbconcept/default.html (1998)
16. Stilgoe, J.R.: Outside Lies Magic: Regaining History and Awareness in Everyday Places. Walker and Company, New York (1998)
17. Tsui, C.: Multimedia Data Integration and Retrieval in Planning Support Systems. M.S. thesis, Department of Urban Studies and Planning, Massachusetts Institute of Technology, Cambridge, MA (1998)

18. Whittaker, S. O'Conaill, B.: The role of vision in face-to-face and mediated communication. In: Finn, K.E., Sellen, A.J., Wilbur, S.B., (Eds): Video-Mediated Communication. Lawrence Erlbaum Associates, Hillsdale, NJ (1997) 23-49
19. Whyte, W.: The Social Life of Small Urban Spaces. 16mm film. Municipal Art Society of New York, New York (1984)