Digital City Kyoto:
Towards A Social Information Infrastructure

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Abstract. This paper proposes the concept of digital cities as a social information infrastructure for urban life (including shopping, business, transportation, education, welfare and so on). We propose the *three layer architecture* for digital cities: a) the *information layer* integrates both WWW archives and real-time sensory information related to the city, b) the *interface layer* provides 2D and 3D views of the city, and c) the *interaction layer* assists social interaction among people who are living/visiting in/at the city. We started a three year project to develop a digital city for Kyoto, the old capital and cultural center of Japan, based on the newest technologies including GIS, 3D, animation, agents and mobile computing. This paper introduces the system architecture and the current status of Digital City Kyoto.

1. Introduction

As the number of Internet users is continuing to increase, various community networks are being tested [1]. The Internet is used not only for research and businesses but for everyday urban life. While the Internet makes research and businesses global, life is inherently local. The concept of digital cities is thus proposed to build an arena in which people in regional communities can interact and share knowledge, experience, and mutual interests.

Various digital cities have been created around the world. In the US, America Online (AOL) has developed a series of digital cities [2]. Each AOL digital city collects tourist and shopping information of the corresponding city. The success of AOL digital cities shows that people need regional information services for their everyday life. Since the word "digital city" is a registered trademark of AOL, though there are numerous activities on regional community networking in the US, we cannot find any other activity named "digital city" in the US.

In Europe, on the other hand, the European Digital Cities Conference has been held annually from 1994 to discuss a wide variety of topics including “the role of cities, towns, and regions in the deployment of advanced telematics solutions within the development of the Information Society.” As an example of the experiments performed, Digital City Amsterdam was started four years ago. This city was built as a platform for various community networking systems and thus particularly focuses on social interaction among digital citizens. We were able to see how social interaction increased in the digital city. Though Digital City Amsterdam succeeded to introduce the city metaphor in the regional information services, since there is no direct mapping between digital and physical Amsterdam, the ratio of Amsterdam based digital citizens decreased from 45% in 1994 to 22% in 1998 [3]. This fact highlights the design issue of how much reality we should put into digital cities. If we make digital cities without strong connections to the corresponding physical cities, the connection may gradually disappear.

Recent activities on digital cities typically include 3D technologies. We can find several VRML-based trials such as those for Helsinki [4], Berlin, and Washington D.C. The Virtual Los Angeles [5] is designed to allow community members to directly participate in the urban planning process, and is a good example of a high quality 3D virtual city. The question is, however, what level of 3D reality is technologically and psychologically appropriate for implementing digital cities. Another question is who should/can develop and maintain the 3D digital cities. Moreover, as the 3D models become more accurate, more computational power and communication bandwidth are required to view digital cities at home. Though there exist various technical and organizational problems on implementing and using 3D in the Internet, we think the 3D technology will take an important role in establishing connections between digital and physical cities.

In October 1998, we started a project to develop a digital city as a social information infrastructure for Kyoto. Digital City Kyoto makes available different city metaphors: a 2D map and a 3D virtual space, which are easy to understand for non-technical people. WEB information is collected and linked to the 2D/3D city. Real-time sensory data from the physical city is also mapped to the digital city. People can get information related to the physical city such as traffic, weather, parking, shopping, and sightseeing. Digital City Kyoto also encourages social interaction among residents and tourists. This paper describes the basic concepts of digital city design in Section 2, and reports the current status of Digital City Kyoto in Sections 3 to 5. Since digital cities create regional information spaces in the Internet, we will discuss cross-cultural communication for bridging digital cities in Section 6.

2. Design Concepts for Digital Cities

The first design policy for Digital City Kyoto is to make it *real* by establishing a strong connection to physical Kyoto. Our digital city is not an imaginary city existing only in cyberspace. Instead, our digital city complements the corresponding physical city, and provides an information center for everyday life for actual urban communities. We think “digital” and “physical” make things “real.” For example, in computerized organizations, such as universities and advanced companies, we cannot figure out their activities without looking into networks (E-mail, WEB and so on). As in those organizations, digital activities will become an essential part of urban life in the near future. The second design policy is to make the digital city *live* by dynamically integrating WEB archives and real-time sensory information created in the city. We will not produce contents nor select them. We will provide a tool for viewing and reorganizing vivid regional information created by people in the city.

We propose the system architecture of digital cities as follows. Figure 1 shows the three layer model for designing digital cities. The first layer is called the *information layer* where WWW archives and realtime sensory data are integrated and reorganized using the city metaphor. The geographical database is used for the integration of those types of information. The second layer is called the *interface layer* where 2D maps and 3D virtual spaces provide an intuitive view of digital cities. The animation of moving objects such as avatars, cars, busses, trains, and helicopters demonstrate dynamic activities in the cities. If the animation reflects real activities of the corresponding physical city, each moving object can become a media for social interaction: you may want to click the object to communicate with it. The third layer is called the *interaction layer* where residents and tourists interact with each other. Community computing experiments [6,7] especially agent/multiagent technologies are applied to encourage interactions in digital cities.

Interaction

Agent supported social interaction among residents and tourists.

Interface

2D maps and 3D graphics.
Realtime animation for interface agents.

Information

WWW, digital archives and realtime sensory data from the physical cities.

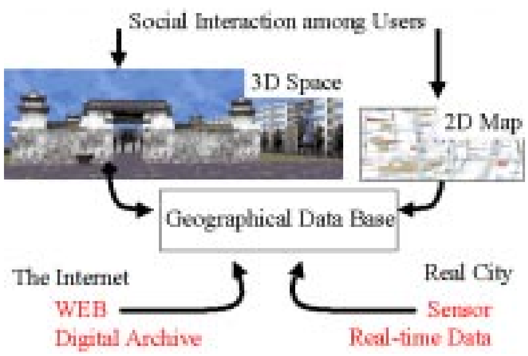


Figure 1: The Three Layers Model for Digital Cities

3. Human Interface in Digital City Kyoto

To explain Digital City Kyoto, we start with the second layer, the *interface layer*. The human interface of current WEB sites is mainly by text: users search information by keywords and software robots retrieve information. This search-and-retrieve metaphor works well, especially if the needed information is distributed worldwide. The AOL digital cities inherit the same metaphor for their interface design. As the Internet is used for everyday life, however, we believe that the geographical interface will become more important in digital cities.

In Digital City Amsterdam, 2D maps represent an abstract city consisting of more than thirty squares with cultural, recreational, technological, civic, and political themes. Though the city does not directly correspond to the physically existing city, Digital City Amsterdam introduced geographical metaphors and spatial constraints, and succeeded to introducing neighboring feelings in digital citizens. If we want to integrate WEB information and real-time sensory data, however, we need more direct mapping between physical and digital cities. In Digital City Kyoto, we thus adopted GIS (geographical information system) as the core of the system architecture. Figure 2 shows maps for Kyoto with two different scales (left: 1/100,000, right: 1/1000). These maps are commercially available at reasonable prices. One interesting technology we are planning to apply is to omit irrelevant details and to produce a simplified map that is intuitively easy to understand.

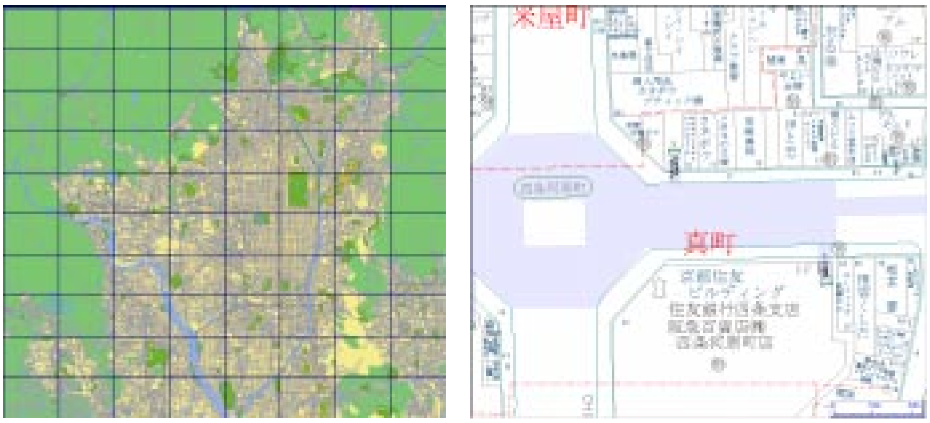


Figure 2: 2D Maps for Digital City Kyoto (Provided by Zenrin Corp.)

The 3D graphic technology becomes a key component of the interface when used in parallel with the 2D maps. The 3D aspect to a digital city allows non-residents to get a good feel for what the city looks like, and to plan physical visits. Residents of the city can use the 3D interface to pinpoint places or stores they would like to visit, and to test walking routes.

VRML (Virtual Reality Modeling Language) is the most well known 3D WEB technology and has been used in various digital city projects. Though VRML has been available for years, it is surprising that 3D technologies on the WEB have not yet become common. Some problems with VRML are its slowness and difficulty in modeling complex objects. Without significant effort, it is difficult to create a realistic VRML space that doesn't look like a plastic model. Though there are various approaches for building 3D experiences, we started with 3DML [8] for our initial prototype. People are comfortable moving through 3D spaces with game interfaces such as those currently offered by Doom or Quake, and now offered by the 3DML WEB plug-in. We decided to use photos mapped onto 3D blocks and 2D planes, rather than precise 3D modeling. This approach does not solve all the problems, but significantly diminishes some of them. Since 3DML coding is far more intuitive than VRML, the costs of developing the 3D space is dramatically reduced. Several days of VRML programming can be equivalent to several hours of 3DML coding. We are able to achieve sufficient graphic realism and detail, while at the same time an average PC can perform the 3D walk through. Some problems exist when downloading gif or jpeg compressed photos: as with any site on the WEB using many graphics, it takes some time when using telephone line connections.

Figure 3 shows the 3DML implementation of Shijo Shopping Street (Kyoto's most popular shopping street) and the hundreds of years old Nijo Castle in Kyoto. 3DML is not well suited to reproducing gardens and grounds, but has no problem with modern rectilinear buildings. Since 3DML is easy to use, college students in Kyoto have started to join us in cooperatively building the 3D Kyoto. This follows the "bazaar approach" to software development (Eric Raymond, The Cathedral and the Bazaar http://www.tuxedo.org/~esr/writings/cathedral-bazaar/). We hope that have contributors from all over Kyoto will keep the project from being a small handful of stagnant areas, and make this a vast and dynamic city.

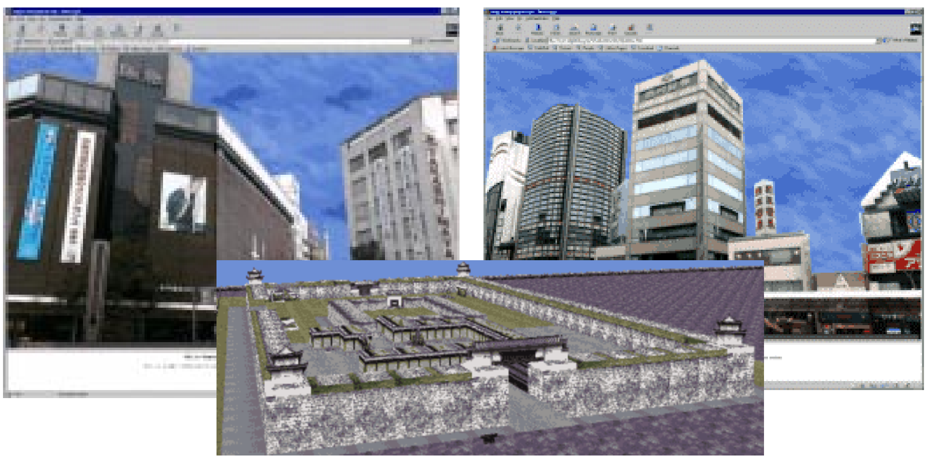


Figure 3: 3D Interfaces for Digital City Kyoto (By Stefan Lisowski)

As described above, we are developing a human interface to Digital City Kyoto that combines 2D maps with several 3DML spots. At the same time, we started discussing various problems with the shopping street community: since we are using photos, information in the photos becomes old; the advertisements in the photos quickly become out-of-date; and some photos include registered trademarks. It is important for engineers, researchers and shop owners to start thinking of these issues. One solution we're working to implement, is a WEB and ftp interface to allow individual shopkeepers to update the advertisement photos on their 3D buildings by themselves.

3D Kyoto impacts different research areas such as architecture and disaster protection. In the area of architecture, researchers are eager to have a digital environment for simulating interactions between humans and environments. Since 3D Kyoto can be run on PCs connected to the Internet, network simulations with a large number of participants become feasible. In the area of disaster protection, the researchers normally must investigate a lot of photos (for example, 12,000 photos for one destroyed city). One group in Kyoto University has been trying to post all those photos on the WEB, but 3D technology may provide a better solution. Though it is impossible to make a precise 3D model for destroyed cities, the photo-based 3D approach can overcome this problem, see Figure 4 which consists only of 3D cubes and 2D planes, plus gif files with transparency.

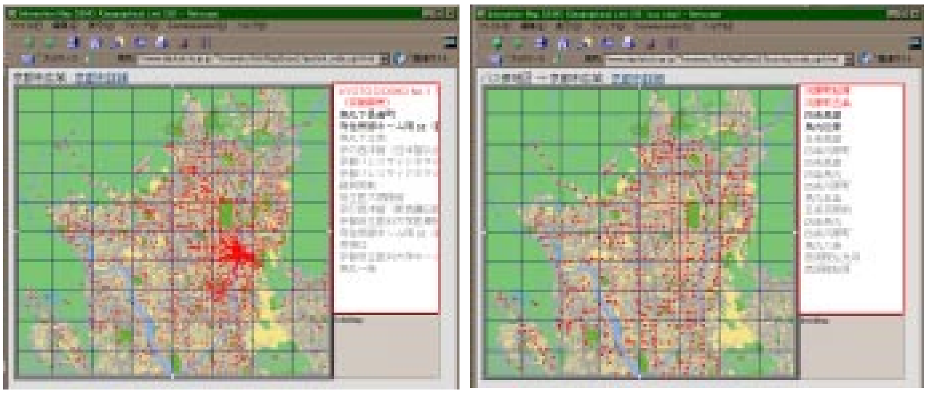
Figure 4 : 3D City after the Earthquake (By Stefan Lisowski)

4. Information Sharing in Digital City Kyoto

The digital city integrates WEB and sensory data. As shown in Figure 1, GIS is the core of the system. The geographical database connects 2D/3D interfaces to WEB/sensory information. From the viewpoint of system architecture, it is also important not to directly connect the interface and information layers. Introducing the geographic database allows us to test various interface/information technologies independently.

After digital cities become popular, people will register their pages to their digital city, but until then, we need some technology to automatically determine the XY coordinates of each WEB page. The automatic address conversion thus becomes a key technology for providing fresh information from the Internet. While the ratio of the Internet users in Kyoto is less than 10%, the number of pages is increasing rapidly. We thus started extracting addresses from the WEB pages and converted them into XY coordinates using the geographic database. The WEB pages, which we could assign XY coordinates, should include precise addresses, famous and unique landmarks, or precise route information. In Kyoto, however, since the city is 1,200 years old, there are various ways to express the same address, and this makes the process very complicated. We have gathered over 600,000 pages that we acquired at a Yahoo regional link and have started developing a learning agent to extract rules for selecting valuable WEB pages and determining XY coordinates from the information contained in the WEB pages. So far, we selected 4,000 candidate pages and determined the precise XY coordinates for 2,000 of them.

Figure 5(a) shows the results of locating those pages on the 2D map. We can see how WEB pages are distributed in the city. The interesting fact is that most of them are located in the center of the city: the main shopping area of Kyoto. Various new data retrieval methods are now under development. Figure 5(b) shows the result of retrieving WEB pages for bus stops in Kyoto. The result clearly shows where those bus stops are located. It appears that the side effect of geographical WEB retrieving is to display the spatial distribution of the retrieved objects in the city.



(a) WEB Sites in Kyoto (b) Bus Stops in Kyoto

Figure 5: Locating WEB Pages on the 2D Map

As the real-time sensory information, we are considering bus schedules, traffic status, weather condition, and live video from the fire department. In Kyoto City, for example, more than three hundred sensors have already been installed and they are gathering the traffic data of more than six hundred city buses. Each bus sends its location and route data in every few minutes. Such dynamic information makes our digital city live. During the first trial we are using real-time bus data and display them on the digital city. Since we can simulate the ideal bus schedule, the differences between real and ideal clearly indicate to users the traffic status. In future, we expect to get information from various private companies such as the availability of parking lots, restaurant tables, and so on. WEB retrieval under the constraint of sensory data is definitely an interesting research issue. We can also use real-time information to make a plan for daily shopping.

Other obvious real-time data is the location of the users, both tourists and residents, in the actual city. Several technologies such as GPS (Global Positioning System) are becoming available to locate each user's position. Real-time city information is more important for people who are doing something in the physical city than for those who are sitting in front of desktop computers. For example, people would like to know when the next bus is coming, where the nearest vacant parking lot is, whether they can reserve a table at the restaurant, and what is on sale at the department store just in front of them.

However, mobile users face limitations in operating their devices. Furthermore, their circumstances and context to get information dynamically change while moving [9]. We are now implementing a prototype application providing live information to mobile users. This application supports them in getting to their destinations within the city by public transportation, mainly by bus. Since in Kyoto, just as most big cities, buses hardly keep to their schedule because of heavy traffic jams, real-time bus information is sometimes more important than the timetable.

5. Social Interaction in Digital City Kyoto

Social interaction is an important goal in digital cities. Even if we build a beautiful 3D space, if there is no one living in the city, the city cannot be very attractive. Similarly, even if we have a virtual town where people often visit to chat, if there is no connection to the corresponding physical city, this town cannot be an information infrastructure for the city.

We plan to use both experimental and traditional digital community building tools to encourage social interaction in Digital City Kyoto. Traditional tools will include newsgroups, email lists, and bulletin boards. We have set up a newsgroup server, and we plan to use this server to encourage both local and tourist conversations about topics that are relevant to real life in Kyoto. Visitor newsgroups might include topics such as stories about travel experiences in Kyoto, best things to bring on one's trip, best restaurants for different kinds of cuisine, and so forth. Local newsgroups might include requests for more specialized sorts of resource help, such as the best place to find and buy a special item, or places for people with a particular hobby to meet. Newsgroups and email lists are very approachable and comfortable technologies for newcomers to the internet, and we hope that providing these simple-to-use resources will encourage visitors and locals to establish thriving community exchanges on the Digital City Kyoto site, that help them in their real life activities in Kyoto.

We are also interested in developing new ways to encourage community to form, using cutting-edge technologies, and ways to support social interaction among residents and visitors. One way we hope to encourage cross-cultural interaction in the Digital City, is by implementing a digital bus tour for foreign visitors to the site. The tour will be a point of entry for foreigners to the digital city, as well as to Kyoto itself. We hope the tour will increase visitor interest in and use of the digital city, and will lead to a richer community around Kyoto Digital City. By providing local information and stories, we hope the tour guide will encourage dialogue and relationships among those participating, both during and after the tour, and will encourage visitors to reach out to and communicate with the local users of the Kyoto Digital City. We also hope that the tour will increase interest in Kyoto's history and lore among friends and family of those who participate, because the stories that the agent tells will be chosen partly based on how easy and attractive they are for retelling to others.

The tour will be implemented within the WEB environment, using I-Chat and Microsoft's Peedy Agent (see Figure 6). The tour guide agent will lead chatting visitors through sections of Kyoto simulated using 3DML. The agent can easily bring up web pages to supplement stories.

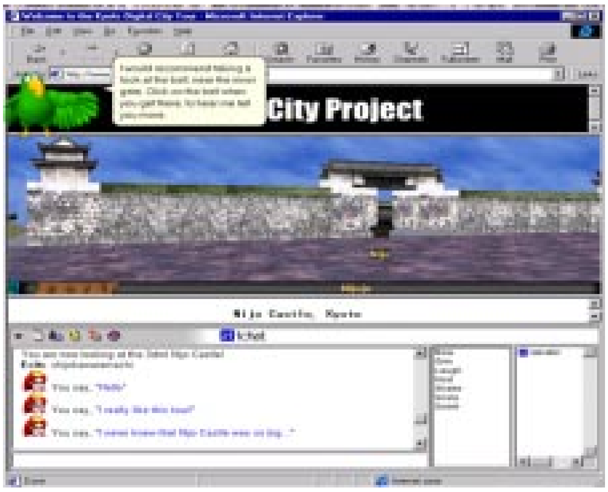


Figure 6: Digital Bus Tour with Agent Guide (By Katherine Isbister)

To prepare for creating the tour guide agent, we participated in several guide-led tours of Kyoto. We noticed that tour guides often told stories, supplementing the rich visual environment of Kyoto with explanations of what Japanese people, both past and present, did in each place. While visitors looked at the buildings, and took things in visually, the guide would create a narrative context for the site, providing visitors with stories they could share with their fellow tour members, as well as with people back home. Tour guides were very sensitive to peoples' interest-level in timing their storytelling, and allowed people time to talk to each other about what they saw and heard. We would like to recreate this sort of rich social and educational experience with our digital bus tour.

We are currently compiling a database of stories related to the sites that will be part of the Kyoto Digital City, and categorizing the stories to allow customization of the tour guide's storytelling. We will use this database to create the agent-led tour of the 3DML interface to the Kyoto digital city. The agent's tour narrative will be triggered by the group's approach to each of the sites on the tour. We plan to vary the agent's narrative to adapt to each visitor group's interest level. Current ideas for tracking visitor interest include noting the amount of conversation among visitors within the chat environment, searching for positive conversation key words while at the site, as well as directly asking visitors in prototype tours to rate stories and to indicate if they would like more information and/or stories about a site. We plan to develop and incorporate direct feedback mechanisms into the final interface to the guide agent, as well. We are also interested in extending the tour guide's abilities to make a story-tool that local web-site hosts (such as shop owners or temple leaders) could use to provide stories for tours.

Developing the agent's story-timing mechanisms and user-interest tracking techniques will contribute to the research on the construction of social interface agents, with implications for using such agents in other types of environments. We hope that developing the tour itself will contribute to our larger, social interaction goals for Kyoto Digital City, by helping to build a self-sustaining community within the city, and encouraging foreign visitors to learn more about Kyoto.

Another trial for social interaction in digital cities uses avatars in the 3D space to bridge residents and visitors. Figure 7 shows the animation of avatars walking in cities with a background image. The technology allows a number of avatars to walk around the city in real-time. By making a link between avatars and people walking in the corresponding physical city, we can realize communication between digital tourists and physical residents.

Figure 7: People Walking with Real Images (By Ken Tsutsuguchi)

As the walking motion can be generated by the user's machine via a WEB browser plug-in, only the walking position/velocity and direction needs to be downloaded. Thus, large number of 3D human walking animation can be created rapidly in real-time. Aside from the avatar, adding a virtual population makes it possible to activate the digital city. This technology is based on the animation system called WWWalk [10], which simulates human walking along an arbitrary 3D walking path.

6. Cross-Cultural Communication in Digital Cities

Digital cities enable us to overcome the geographical limitations of communication. We can meet people who have different cultural backgrounds in digital environments. Since digital cities create regional information spaces in the Internet, cross-cultural communication becomes an essential issue. Then, how we can support cross-cultural communication in digital cities? To support worldwide business, standardization of data formats such as CALS in electronic commerce has been extensively studied. However, for human communities, standardization can not be a solution. In this section, we discuss a digital environment that can mediate cross-cultural differences.

We have developed an embodied character that acts in a three-dimensional meeting space called FreeWalk [12]. It is sometimes difficult to begin talking if users have different cultural backgrounds. The helper character provides common topics to break the ice. We loaded safe and unsafe topics into the conversation database of the character. Figure 8 shows a three-dimensional meeting space where the character is posing a question to users.

Figure 8: FreeWalk with a Helper Character (by Hideyuki Nakanishi)

Suppose a group of people with different cultural backgrounds is planning to work collaboratively. It is important to know each other beforehand to make the remote collaboration run smoothly. We have developed a system that uses a large electronic screen called Silhouettel to help the socialization process [13]. Figure 9 shows how this system works in a media room. When the two screens are connected by high speed network, the system overlays video images of two separated groups on a large screen, and shows personal information, such as name, cultural information (e.g. nationality, language), and information about the collaboration (e.g. period, skill) in both languages. The user can change the information displayed by touching the menu on the screen. By integrating the system into the digital city framework, we think that groups of people in different digital cities can collaborate with each other.

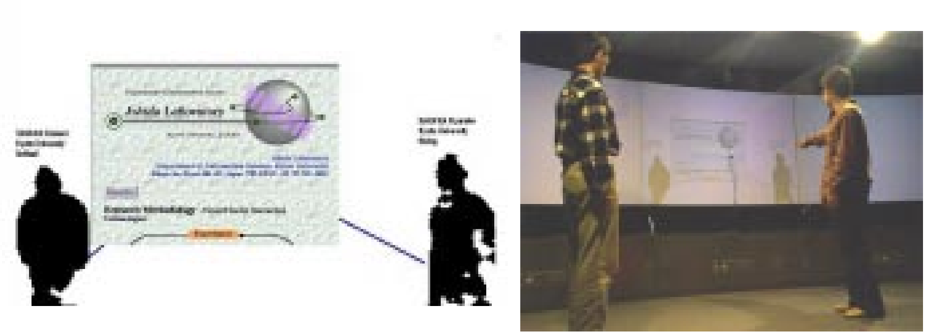


Figure 9: Silhouettel (by Masayuki Okamoto)

We are conducting a social psychological experiment to test the effectiveness of those systems using an international dedicated line between Kyoto University and Stanford University to see how this system contributes to communication among different cultures.

7. Conclusion

The Digital City Project is a three-year initiative sponsored by NTT. Established in October of 1998, the project consists primarily of researchers from NTT and Kyoto University, but also includes a wide variety of people from other organizations. Contributors include several different universities in Kyoto and leading computer companies. Researchers and designers from overseas have also joined the project.

Besides technological problems, we have encountered numerous non-technical research issues such as security, privacy, and intellectual property rights. To gain a better understanding of the big picture of digital cities, we are planning to have an International Symposium and Workshop on Digital Cities in Kyoto, in September 1999. Through designing Digital City Kyoto, and collaborating with worldwide activities on digital cities, we hope to develop an avenue towards the social information infrastructure for urban life in the 21st century. All activities of Digital City Kyoto can be found at http://www.digitalcity.gr.jp/.

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