Activities and Technologies in Digital City Kyoto

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Abstract. We have developed a digital city for Kyoto, the old capital and cultural center of Japan, as a social information infrastructure for urban everyday life including shopping, business, transportation, education, social welfare and so on. The project was initiated by researchers in NTT and Kyoto University in 1998. In 1999, the Digital City Kyoto Experimentation Forum was launched. The forum includes several universities, local authorities, leading computer companies, local newspaper companies, historical temples, as well as photographers, programmers, students, volunteers and so on. Researchers and designers from overseas have also joined the project. One of the salient features of Digital City Kyoto is that computer scientists from universities and companies have continued to play a leading role in the organization. As a result, Digital City Kyoto is based on the newest technologies including GIS, VR, animation and social agents. The *three-layer architecture* for digital cities has been proposed: a) the *information layer* integrates both Web archives and real-time sensory information related to the city, b) the *interface layer* provides two and three dimensional views of the city, and c) the *interaction layer* assists social interaction among people who are living/visiting in/at the city. In this paper, the organization and activities of three year experiments, from 1998 to 2001, named Digital City Kyoto, and the technical/social lessons we have learned are described in detail.

1 Why Digital Cities?

Many of the problems created in the 20th century, such as crowding, environmental pollution, food and energy crises remain to be solved in the 21st century. Effective solutions require the existence of a global consensus mechanism based on the Internet. In addition to negotiation at the national level, cross-border collaboration among countries and communities will form an essential part of the consensus mechanism. Intercultural interactions in daily life equal the importance of formal discussions held at inter-governmental conferences.

The notion of digital cities can be defined as follows: *digital cities will collect and organize the digital information of the corresponding cities, and provide a public information space for people living in and visiting them to interact with each other*. Digital cities have been developed all over the world, and can be connected to each other via the Internet, just as physical cities are connected by surface and air transport systems.

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Why do regional information spaces attract people given that we are in the era of globalization? We realize that the Internet has fostered global businesses, but at the same time, it enables us to create rich information spaces for everyday life. While the Internet makes businesses global, life is inherently local. Business requires homogeneous settings to allow global and fair competition, while daily life can remain heterogeneous reflecting our different cultural backgrounds. If differences exist in business, standard protocols are needed to overcome them, but we do not need any standard for social interaction. If the differences are significant, we should develop support tools for intercultural communication.

Table 1. Two Extremes in Internet Use

Business	**Everyday Life**
Global	Local
Market (Competitive)	Community (Collaborative)
Homogeneous	Heterogeneous
Standard Protocol	Intercultural Communication

Table 1 shows two extremes of Internet use. The table does not mean that the two types of usages are always disjoint, various combinations are common in Internet use. The motivation for studying digital cities is to shift our view of Internet use from one side (business) to another (everyday life). Both perspectives should be combined to build a public information space in which people can participate and interact, and to create the consensus needed to tackle the various problems. The rest of this section discusses each of the aspects in Table 1 further to clarify our motivation with regard to digital city research.

1.1 From Global to Local

With the development of the Internet, economies of scale have made business activities more global. Even small companies can participate in the worldwide business network, since the Internet significantly reduces search and negotiation costs to find partners and markets. The Internet makes commercial transactions much easier in most business areas. On the other hand, globalization is not so frequent in everyday life. Although the Internet has widened the information channels available, it cannot physically move people. Statistics show that people still spend their income for housing, shopping dining and so on where they live. Everyday life substantially remains local even though the Internet offers international reach.

Digital cities should support our everyday life. It is natural for people living in a city to create a public information space that corresponds to the physical city. The question is, however, whether or not it represents an efficient usage of the Internet. The Internet is often viewed as a new continent. For example, the Internet yields the possibility of building a virtual mall comprising a huge number of shops that cannot exist in any physical city. The locality of digital cities might constrain the possibilities inherent in the Internet.

To discuss this issue, we examine the interesting example of a shopping street community in Kyoto. The community consists of 3,000 Kyoto shops. They jointly started a site that enables customers to make electronic account settlements by debit and credit cards. Purchasing requests from within or beyond the local community are processed electronically and goods are delivered by logistics companies. As a result, many Kyoto shopping streets now appear on the Internet. Thousands of shops are already offering services under this framework. At first glance, this seems to be just another form of global virtual mall like Yahoo. However, its business model is totally different.

Global virtual malls are often called platform businesses. Providers of the platform offer reliable and trustful sites, and invite suppliers as well as customers. It does not matter whether or not the suppliers have a presence in the physical world. The Kyoto shop alliance, on the other hand, represents real world entities. Credibility has been established through the long history of physical Kyoto. The question is how this local mall can compete with huge existing global virtual malls. The Internet naturally encourages economies of scale and it appears hard for small malls to achieve success because they offer fewer services. It seems that local malls, which are hard to scale up, cannot compete with global malls. This, however, is not the entire story if consumers are interested in the city as a whole, not just buying goods. In this case, a digital city, which creates a whole city in the Internet, can support local malls.

1.2 From Market to Community

According to Webster's Dictionary, the word *community* is defined as "a body of individuals organized into a unit or manifesting usually with awareness some unifying trait." More specifically, Hillery reported that there were at least 94 definitions for this word even in the early 1950s [4]. His summary of the factors of community showed that they include *locality*, *social interaction* and *common ties*. MacIver also pointed out that the concept of community is based on the locality of human life, and is the counter concept of *association*, where people share a common goal [15].

With the advance of global computer networks like the Internet and mobile computing, discussion of the virtual community has become more active. The term *community* is being used as a metaphor for the next stage of computing technologies, including the methodologies, mechanisms and tools for creating, maintaining, and evolving social interaction in human societies. We believe there will be a dramatic shift in computing metaphors: from *teams* and *markets* to *communities*.

We first address how to extend technology called *groupware* (designed for team work) to *communityware* for community support. In the 1980's, research on groupware was triggered by the advance of local area networks. Though there is no specific definition of the term *group*, previous research into groupware mainly addressed the collaborative work of already-organized people. Various tools have been developed for communication among users in different places. A typical example is where project members in the same company synchronously/ asynchronously work using workstations connected by local area networks.

The word *communityware* has been created for more diverse and amorphous groups of people [7,8]. The metaphor of community has become important given the advance of global computer networks such as the Internet and mobile computing. The

goal of communityware is to support the process of organizing people who are willing to share knowledge and experience. In other words, compared to groupware studies, communityware focus on an earlier stage of collaboration: group formation from a wide variety of people.

Table 2. Teams, Communities and Markets

	Teams	**Communities**	**Markets**
Network	LAN	Internet	Internet
Agent number	10^1-10^3	10^2-10^4	10^3-10^5
Organization	Closed Collaborative	Open Collaborative	Open Competitive
Computational Model	Cooperative Problem Solving	NA	Market-based Computing
Example Application	Groupware Work Flow	Community Network Digital City	Network Auction

Every community has rules that can be represented logically. The rules may specify how to elect leaders, make decisions, to collect monthly fees, and so on. Groupware technologies can provide tools for supporting these formal procedures. In the case of communities, however, people require more than logical support. For communities, it is essential for members to share feelings such as *we-feeling*, *role-feeling,* and *dependency-feeling* [15]. The obvious question is whether community feelings can be established and maintained within a virtual space like digital cities. The challenge is to enrich the human community in physical cities through the use of digital cities. Therefore, communityware should become a key technology for digital cities.

While the Internet has created worldwide competitive markets, daily life is more collaborative. A concept that counters the global market is the local community. Compared to the computational study of markets, however, studies on communities are still immature. Given that the team and market metaphors have created research fields like groupware and network auctions, however, it is quite possible that the community metaphor will generate new fields in both research and practice. Table 2 compares the three different metaphors.

1.3 From Homogeneous to Heterogeneous

When we search for "digital cities" in the US, we find many instances created by America Online (AOL). AOL provides locally focused online network services for several hundred cities and the number is still growing. Each AOL digital city collects tourist and shopping information of the corresponding city. Besides those information services, AOL provides local advertising opportunities for vertical markets including auto, real estate, employment and health. The AOL digital cities form the largest and most popular local information service in the US. The success of AOL digital cities shows that people need regional information services for their everyday life.

The feature of AOL digital cities is that, as with other commercial portals, the efficiency of site creation is paramount since it is aimed at business. As a result, the hundreds of AOL digital cities have almost the same face. Though the information

sources are different, the tools they use are standard and the way of organizing information is homogeneous. It is inevitable that commercial sites will be constructed in such a way, since even if hundreds of physical cities were to be built, the same tools and design methodologies would be employed by the same company.

European digital cities represent a more bottom-up approach. The organization named TeleCities promotes information and technology sharing in Europe. Each city develops its digital equivalent following its own direction. Consequently, digital cities in Europe have different faces [17]. Similarly, Digital City Kyoto has a unique organizational structure because of the historical background of physical Kyoto. Cost efficiency should not the main goal for creating this digital city. What we look for is not the efficiency of accumulating information but the differentiation of public information spaces to reflect the cultural backgrounds of Kyoto.

1.4 From Standard Protocol to Intercultural Communication

There are two reasons for discussing intercultural communication in the context of digital cities. The first is that, in any city in the world, the citizens are becoming more diverse. A public information space can play a major part in bridging the cultures. The second reason is that a digital city will represent a real city on the Internet. We have 40 million visitor-day annually in Kyoto, but we expect more people will visit Kyoto via the Internet. Therefore, intercultural communication must be supported, even though the main purpose of digital cities is to support the everyday life of local residents. A local information space and a platform for intercultural communication are two sides of the same coin.

Kraut reported that the Internet impacts both cosmopolitanism and domestication. In the HomeNet project [12], he observed that the number of long distance e-mails increased as people became more familiar with the Internet. At the same time, the Internet strengthens family ties: e-mails are also used as a communication tool within the family. Digital cities will have the same effect. A site with local everyday life eventually becomes a nexus linking residents to visitors from overseas.

We should be aware that the ratio of English Web pages worldwide has been decreasing rapidly. As the Internet will be applied to everyday life more and more, the ratio of English Web pages will keep on decreasing. It is obvious that the need for intercultural communication will increase significantly. Without linguistic and cultural support tools, it is not possible for people to create productive interaction. The latest machine translation technologies can increase the opportunity to participate in intercultural communication.

2 Activities in Digital City Kyoto

2.1 Design Policy

There are several policy options in building a digital city. Kyoto was the capital of Japan for more than a thousand years, and has been the cultural center of Japan for

even longer. To begin a digital city project for Kyoto, we started with its design policies.

The first option is to select either a top down (centralized design) or bottom up (self organizing) approach to build the digital city. As mentioned earlier, city portal services provided by companies apply the same tools and systems to different cities mainly to maximize cost efficiency. Though the information accumulated differs, all commercial digital cities have a homogeneous structure. On the other hand, the US community networks and most European digital cities are heterogeneous, having different architectures and interfaces [17].

We tried to respect the long history of Kyoto when building Digital City Kyoto. We did not specify tools for its creation. We allowed our colleagues to use any technology, any software and any content. We tried to build a public information space from the bottom up. The unique aspects of Kyoto, which were not noticed at the beginning of the project but discovered through building Digital City Kyoto, include historical and cultural accumulation, closed and self-reliant communities, and plenty of rich personal Web pages. A single Web building package is not enough to describe all of the aspects of Kyoto.

The second option is how closely the physical and digital cities should correspond. We adopted the policy of making Digital City Kyoto *real* by establishing a strong connection to physical Kyoto. Unlike GeoCities, 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. Digital activities will become an essential part of the real city in the near future. We think "digital" and "physical" make things "real." We are thus working on a digital version of the real city.

How strongly are other digital cities connected their physical origins? Helsinki [13,14] was planning to build a high-speed metropolitan network. Under this plan, to fully utilize the new network, the digital city must be tightly connected to the physical Helsinki. This is why the 3D virtual city is the core of the project. Amsterdam seems quite different [2,3]. This digital city is not directly connected to physical Amsterdam. The inhabitants of large metropolitan areas, like Amsterdam, mostly come from other cities. Their interests are not necessarily focused on Amsterdam. Though Digital City Amsterdam succeeded in introducing a city metaphor into 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.

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. The Amsterdam organizers thought of this as a good sign. This is probably because of the size of the country and a role of the city in the country. In the Netherlands, there are 14 million people living in a small area. Amsterdam is the capital and 1.5 million people live in the greater Amsterdam area. The political power of Amsterdam makes it possible for the digital city to keep centripetal force beyond the physical boarder of the city. There exists a reason why the project welcomed the growth of the digital city beyond its boarder.

In the case of Digital City Kyoto, since its goal is to create a social information infrastructure for Kyoto, we set very strong links between the digital and physical cities. As the level of real-time sensory data continues to be increased, the linkage

becomes strengthened even further. There is no reason to restrict communication within the city. However, when we started the project, only 10% or so of the population in Japan were Internet users, and most were young "office workers familiar with technology." Accordingly, the Internet has had a very limited influence on daily life. Due on this fact, the goal of the digital city project (to create a social information infrastructure of Kyoto) may become vague without the strong connection. While Amsterdam is the capital of Netherlands, Kyoto is not. Netherlands can be the border of Digital City Amsterdam, but Japan is probably too large to act as the border for Digital City Kyoto. The strong connection between digital and physical Kyoto was designed by assessing the Amsterdam experience.

The third option is the communication media used. It is well known that selecting media influences not only communication bandwidth but also the semantics of messages. It has been only ten years since the Internet began to influence the world. We are just beginning to see the impact of Internet use on everyday life. The current Internet technology can efficiently handle logical information like research and business documents. However, the information necessary for everyday life is more informal. While Web mainly provides texts and pictures, peer-to-peer communication with videos or sounds will soon be feasible. The issue is to select the appropriate media for services in digital cities. Though new technologies are not always useful for current services, we believe it is worth trying them for new services. Since many research organizations are gathered in Kyoto, e.g. Kyoto University, NTT Communication Science Laboratories, ATR, CRL (NICT fron 2004) etc., we decided to pursue new technologies for designing our digital city.

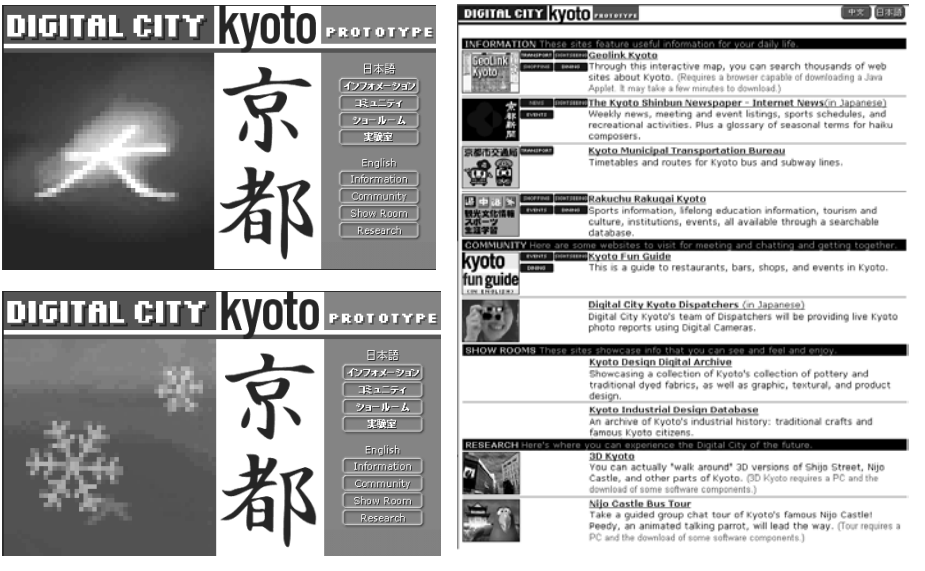
As a summary, the design policy of Digital City Kyoto is to create a public information space in a bottom up fashion, to directly connect it to the physical Kyoto, and to develop it around the latest technology.

2.2 Services

Figures 1(a)(b) show screen shots of the top page of the Digital City Kyoto prototype. They were designed by Ben Benjamin, a graphics designer in Los Angeles. Four-season shots overlay the Daimonnji (mountain) in a GIF animation. Benjamin joined this project during a one-year stay in Kyoto. He also designed a link list that is static but offers simple and impressive color combinations. Japanese, English (Figure 7.1(c)), and Chinese link lists are available from the top page. The Chinese link list was created by Chinese students in Kyoto triggered by a call from Jouin Teramae, the chief priest of Kodaiji (temple). Like the English page, the link list is the only page that is translated into Chinese, and almost all linked pages are written in Japanese. Though an active discussion was held on translating every Japanese page into English or Chinese, it did not work because of open issues such as a copyright policy and the responsibility for mistranslations. Services provided are divided into four categories, "Information," "Community," "Showroom" and "Laboratory." This classification is quite different from those of other digital cities and community networks. However, this is the result of dividing the services of Digital City Kyoto into groups of about the same size. The four classes show the current Internet activities in Kyoto. In particular, "Showroom" and "Laboratory" reflect Kyoto's features, where many cultural heritages and advanced research institutes coexist. The number of services totals 34.

The site also provides links to world digital cities and statistical data on service access frequency.

"Information" is linked to service sites, and contains dedicated regional information sites such as Kyoto Shinbun (newspaper), and Kyoto Municipal Transportation Bureau. Kaoru Hiramatsu devoted himself to setting links to public spaces in the map. This system is called GeoLink [5]. There are more than 5000 linked pages of restaurants, shops, schools, sightseeing spots, shrines, temples, etc. It does not include private Web pages. GeoLink has become the most popular site among the services accessed through the top page. We obtained the permission of all site authors for linking, because it was not clear whether or not a third party could legally link those sites to the map and open them to the public. Most of the sites agreed, however, some of them (for example, kindergarten sites) declined to be linked to the map. Some site authors had a hard time deciding whether they should agree or not. It was not clear for people what would be the impact of linking their sites.



(a) Top Page for Summer (b) Top Page for Winter (c) Link List in English

Fig. 1. Top Page of Digital City Kyoto

"Community" is a category for interaction among participants. Ben Benjamin and Shoko Toda developed a site (Figure 2(b)) for vegetarian visitors from overseas. This site became a precious source of information and a place for interaction because there are not many vegetarians in Kyoto. In the category of "Community," there is a page that cannot be seen in other digital cities. Koichi Yamada and Satoshi Oyama, one of the volunteers who participated in the Experiment Forum, gathered personal Web pages provided by residents of Kyoto, and established the site called PersonalPages. The page was designed by Taeko Ariga (Figure 2(a)). Each personal site offers

remarkably high quality and plentiful information. The number of sites exceeds 25. Every individual site shows the creators' enthusiasm and attachment to Kyoto.

A story of the birth of this site is as follows. One day, I was seated in a taxi going to Kyoto University. The conversation with the taxi driver became lively over a 15 minute period and occasionally we talked about the Internet. The driver told me that he was maintaining his own site as a sightseeing guide. He spent two to three hours per day updating his site, and carefully answering questions from students planning school trips to Kyoto. I explained to him our activities on Digital City Kyoto and got off the taxi. When I accessed his site from my laboratory, I was amazed. "All about Kyoto (Kiwameru-Kyo)" provides plenty of information together with the atmosphere of the ancient capital as it changed from season to season. Even the municipal tourist section does not offer the same atmosphere. It seems that only a volunteer who loves his city and who directly contacts people in the city can create such a site.

(a) Personal Pages (b) Vegetarian Restaurant

Fig. 2. Volunteer Sites in the Category "Community"

"Showroom" is a category peculiar to Kyoto. Cultural heritages are being accumulated electronically through the leadership of Koichi Shimizu, Kyoto Digital Archive Initiative. Many archives such as designs of Nishijin (cloth) and digitized cultural assets are linked.

"Laboratory" shows the technological advances of Digital City Kyoto. Interesting but not yet practical systems are displayed. "3D Kyoto" is a system that is attracting the greatest attention. Stefan Lisowski, the primary developer of 3D Kyoto, came from San Francisco to stay in Kyoto for one year to work with this project. We developed a 1.6km long modern shopping street and historical Nijo Castle in the 3D virtual space. 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. We also received shopkeepers' requests such as: the photos of their shops were not bright

enough; they want the photos to change; and they wanted us to take another photo. Furthermore, some photos had a potential legal problem about registered trademarks. It is important for engineers, researchers and shop owners to start thinking of these issues. It seems to be necessary to develop tools that can support people in the participatory design process. One solution we are working to implement is a Web and FTP interface to allow individual shopkeepers to update the advertisement photos on their 3D buildings by themselves.

The virtual space building tool "3DML" was adopted for this project. Since 3DML is easy to use, college students in Kyoto have started to join us in cooperatively developing the 3D Kyoto. Students of Kyoto Computer Gakuin (school) recreated the area around their buildings using 3DML. This movement has spread to schools like Kansai University and Makino High School in Osaka. This follows the "bazaar approach" to software development. We hope that having contributors from all over Kyoto will keep the project from becoming a small handful of stagnant areas, and make this a vast and dynamic city.

Besides 3D Kyoto, links are available to systems developed by universities or corporation researchers, such as a digital bus tour. We believe that digital cities will be forever changing the technologies used; a dynamic living space cannot be founded on static technology. The name "Laboratory" contributes to establishing a more dynamic view. This category is also important in strengthening the users' image of the future digital city and directing their attention to the future.

2.3 Organization

Digital City Kyoto was established in October 1998. The project is an initiative sponsored by NTT and housed in the new NTT Open Laboratory [1]. The aims of the project are to create next-generation systems for digital communities and to explore basic research issues. The project consists primarily of researchers from NTT and Kyoto University, but also includes a wide variety of people from other organizations. The project has a cross-cultural research team: it includes a social scientist, computer scientists, programmers and designers from U.S. and staff from Japanese industries and universities.

NTT pursued the possibility of cooperating with outside organizations in a social information study, and so invited a research project leader to organize an open laboratory. At the same time, Kyoto University launched a department of social informatics to pursue the inter-disciplinary study in computer science for human society. The reason why a telecommunication enterprise NTT supported empirical study is not same to the Helsinki situation. The open laboratory was set up within the enterprise sections but in basic research laboratories. NTT is trying to open up a new application field together with researchers of outside organizations to find future research issues.

The challenge from NTT was attractive enough for university researchers to take it up. Activities of Digital City Kyoto started in the open laboratory in consultation with Fumio Hattori, the director of NTT Laboratories. The project has conducted fieldwork on digital cities in cooperation with the city government and shopping street communities. The open lab produced all sorts of prototypes over an eighteen-month period: A map-based Web search system, a three dimensional virtual Kyoto, a city

guide by the social agent, and so on. The result was as if an accumulation of computer science technologies met a different field of study and unexpected needs, and energy was generated without restraint.

The key to the success of the open laboratory was that NTT did not stick to the established approaches to computer science, but tried to promote research without restraint. GeoLink, described later, and 3D Kyoto are outcomes of this policy, and it is more suitable to call the project an initiative than a study. In GeoLink, public Web sites are linked to the map, and photos of each building on the Shijo (shopping street) were taken to build 3D Kyoto. This came as a surprise since there was no research schedule or proposal describing this activity when this initiative started. Since the initiative was carried out by basic researchers, the research topics were discovered while 'doing it', the research papers were published afterwards. The open laboratory's norm was "move then think."

The problem of the open laboratory was that ownership of the research results was not well thought through. Once Digital City Kyoto was appeared in newspapers and TV, NTT made use of it in various advertisements. The number of press reports exceeded 20. The extensive coverage, most of which used expressions like 'NTT Digital City Kyoto', raised a paradox in digital city studies. At that time, project members finally realized that there was a dualism about the word "open." For researchers, NTT was offering an open study place for society. For NTT, however, the place was intended to attract the knowledge and energy of researchers outside the company.

The experiences from the open laboratory show the importance of contacting people in the city. For example, the permission of residents is required to link their Web pages from Digital City Kyoto. Legal problems such as handling trademarks could not be resolved by the research group. To increase the level of interaction among researchers, local authorities, people and communities in Kyoto, an open meeting was held at Kyoto University in September 1999. Subsequently, Digital City Kyoto Experiment Forum started activities in October 1999. The period was set to two years on the basis of the open laboratory experience. It was risky to set a longer period in such a rapidly changing field.

At the same time, the Digital Archives Initiative was established in Kyoto to accumulate cultural heritages. Moreover, Kyoto Shinbun (newspaper) started work on Web news. As a result, the Forum gathered over 100 members from more than 30 organizations, who joined on a personal basis: local authorities such as Kyoto prefecture, Kyoto city, fire stations, transportation departments, local town paper, companies such as NTT and NEC, researchers, photographers, resident, priests and volunteers came together. Although the Forum is a collection of individuals, many participants can represent their organizations. Unlike the situation in Europe and the United States, the border between individual and organizational activities is not so rigid in Japan. Companies (participants' bosses) are also conscious of two aims, profit seeking and contributing to society. What the gathered people have in common is a desire for an attractive public information space for Kyoto.

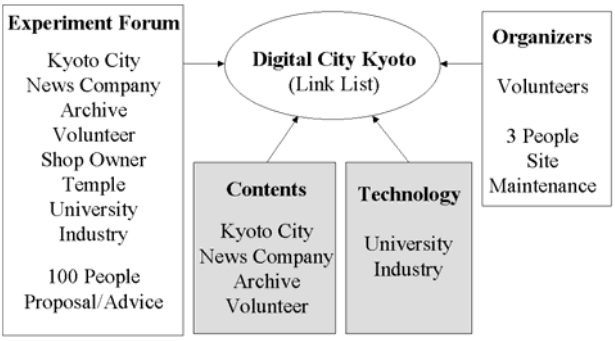


Fig. 3. Organization of Digital City Kyoto Experiment Forum

Site management of Digital City Kyoto moved from the open laboratory to the Experiment Forum at this point. A site created by the Forum was named the "Digital City Kyoto Prototype." The term "prototype" was used to make room for the real Digital City Kyoto, which is hoped to emerge after the experiments, and to achieve the freedom needed to challenge various issues. Figure 3 shows the organizational structure of the Forum. Digital City Kyoto Prototype was essentially a link list consisting of various regional information sites and individual sites. It was not a full-fledged information service site like AOL. There was no permanent staff for information services. The site was maintained by three volunteers who renewed the link list as needed. The policy of linking was simple: "link all interesting trials." When receiving a request for linking, the three volunteers consulted the Forum on the renewed link list. If there was no problem, the new list was released to the public within a few days. The Experiment Forum closed in September 2001 after completion of the two-year period.

2.4 Use and Users

The top page (Japanese) of Digital City Kyoto Prototype was accessed more than 170,000 times in two years. There were more accesses to the link list than the top page. Moreover, the total number of accesses to the linked sites far exceeds those of the link lists. The reason for this is that the linked sites are directly bookmarked by users and search engines. Access to the English link list was about 7% of the total, while access to the Chinese link list was about 2%.

Contents that used new technologies such as Geolink and 3D Kyoto won high ranking in terms of access frequency. Another tendency noted was that real time information such as headline news of Kyoto Shinbun (newspaper company) and Web cameras at Kyoto Gozan (hills) and City Hall were often accessed. Community oriented contents such as Personal Pages and Kyoto Fun Guide were also accessed frequently. According to a time-based observation of access frequency, access number strongly increased right after a press release, but then returned its average value. At the beginning of the Digital City Kyoto Prototype, 3D Kyoto saw more accesses than Geolink, however, they traded places afterward. Given the current

bandwidths available, Internet users in Kyoto have difficulty in using 3D. Although many people accessed it once, not many came back. There was no killer application that made a convincing argument for the 3D interface.

Our survey shows that 69% of users accessing to Digital City Kyoto are from the *jp* (Japan) domain, followed by domains such as *com* and *net*. In the *jp* domain, *ne.jp* was the most common. This means that most users were accessing via commercial providers. We checked the accesses to Chinese and English top pages to investigate the distribution of access by languages. It is found that *tw* (Taiwan) was the main user of Chinese pages, while the English page was accessed by *de* (Germany), *uk* (England), *ca* (Canada), and *au* (Australia).

It is also interesting to know how people access information using a map. According to the access log, *search by address or location*, such as specifying street numbers or station names, accounted for 33.7%, *search by organization,* such as schools or companies, accounted for 24.2%, *search by building* accounted for 11.7%. In total, *search by physical objects* accounted for 69.6% of all accesses. Search by other expressions, e.g. general terms such as "hotel" or "noodle," accounted for 30.4%. There is a clear tendency to use names of physical objects in the city, when using a map interface. It appears that the search behaviors seen in digital cities closely match those in physical cities.

2.5 Lessons Learned

The excitement we experienced over the three years far outstripped our initial expectations. 3D virtual Kyoto has revitalized the local shopping street community. Shijo is the main shopping street in Kyoto, and many stores have histories stretching back hundreds of years. It became the first street in Japan to offer an Internet café, the first street to use the debit card, and the first street to have ISDN lines installed in every shop for Internet connection. The community created a committee called the *informatization initiative*. The members of this committee deeply understand computers and networks. The day we visited the Shijo community with the first prototype of 3D Shijo was unforgettable. The 3D virtual Shijo was supported right away by the committee members. They quickly got permission for building the 3D virtual Shijo from the community. In the century-old community, elderly people never fought against proposals from young reformers saying "Stop, because I don't understand." Instead, they gave encouragement saying "Get on with it, because I don't understand." In a few days, we got their approval, and in a few weeks, the project was introduced to ten other shopping street communities in Kyoto. Requests for another 3D virtual street came from the neighboring community called Gion. It appears that traditional groups contain far more energy for innovation that could be predicted.

In the Experiment Forum, a meeting was held once every few months in which 30 to 50 participants discussed a wide range of topics. The idea of the Digital City Kyoto prototype was widely accepted. The prototype was created in the Forum by a combination of local authorities, companies, universities, and volunteers. Risky but innovative ideas were created in the Forum, some of which were stimulated by the use of the term "experimentation." Photos of shopping streets were published in 3D Kyoto without permission. Translation projects were planned in detail before

resolving the problem of infringement of intellectual property. It turns out that the Forum was extremely useful in promoting new challenges to social problems, and developing understanding gradually in an open community.

Though the Forum attracted a variety of people in Kyoto, the organizational goals of the Forum were vague. The motivations of the participants varied. Many people were interested in the movement and activities in the Forum, but only a few people took initiative. The Forum tried to have its own projects, each of which involved more than two organizations. However, most of these projects ended in failure. The successful projects were created by small groups of confident people, not by large groups created from discussions within the Forum. We experienced two extremes, enthusiasm and stagnation, at the same time. Compared to the participants' expectations, the organizational power of the Forum was very poor.

The greatest success achieved by the Forum was PersonalPages. Our eyes were opened by the many individuals who created rich and personal Web sites. Many qualified volunteers have been playing an active but quiet role in the Internet. PersonalPages succeeded in making those volunteer sites stand out.

To develop a fully-fledged Digital City Kyoto, it was necessary to slim down the Forum to speed up its decision-making process and empower the working groups to create new contents daily. However, it appeared that there are several difficulties hindering Digital City Kyoto. The city municipal government does not like the idea of being involved in a local portal business. They believe the role of authorities is to be restricted to provide basic infrastructures for information services. NTT is worried about the competition between digital cities and its own portals. Although the shopping street communities and newspaper publishers are cooperative, they think they cannot become a primary player. Volunteers and universities are not qualified to manage digital cities. The key to making Digital City Kyoto a success seems whether or not different organizations with different goals can see the common benefits of creating a digital version of Kyoto.

3 Technologies in Digital City Kyoto

3.1 Three-Layer Architecture

To design Digital City Kyoto, we started with a discussion of its system architecture. We proposed the three-layer model illustrated in Figure 4 [7].

1. The first layer, called the *information layer,* integrates and reorganizes Web archives and realtime sensory data using the city metaphor. A geographical database was used to integrate different types of information. We created a tool for viewing and reorganizing digital activities created by people in the city.
2. The second layer, called the *interface layer,* uses 2D maps and 3D virtual spaces to provide intuitive views of digital cities. The animation of moving objects such as avatars, agents, cars, buses, trains, and helicopters demonstrate some of the dynamic activities in the cities. If an animation reflects a real activity, the moving object can become an interesting tool for social interaction: users may want to click on the object to communicate with it.

3. The third layer, called the *interaction layer,* is where residents and tourists interact with each other. Communityware technologies are applied to encourage interactions in digital cities.

The above three-layer architecture is very effective in integrating various technologies. Only a small guideline was required to determine where each technology should be positioned. Some of the technologies developed in Digital City Kyoto are introduced below.

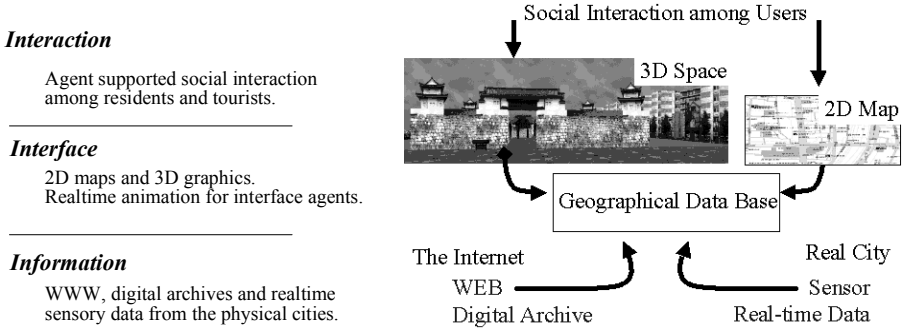


Fig. 4. Three-layer Architecture for Digital City Kyoto

3.2 Information Layer

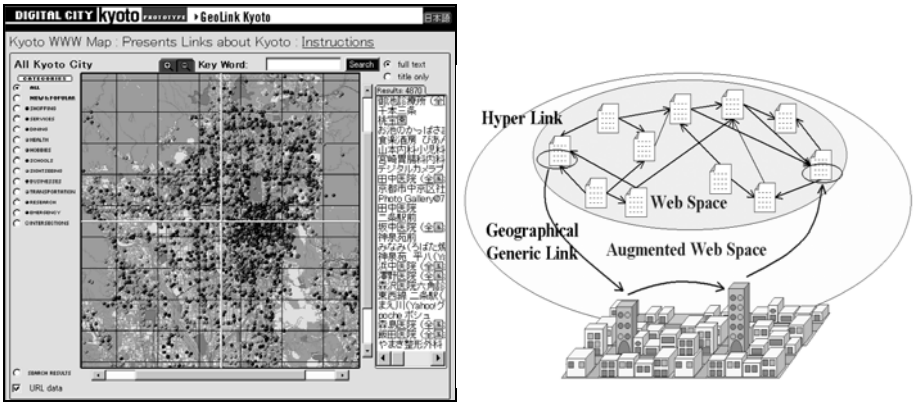
Let us start with the first layer, the *information layer*. Operations on current Web sites mainly involve text: users search information by keywords and software robots retrieve information. This search-and-retrieve metaphor works well, especially if the needed information is distributed worldwide. If the Internet is to be used for everyday life, however, the geographic interface will become more important. As shown in Figure 4, the core of our digital city is GIS. The geographic database connects 2D/3D interfaces to Web/sensor-sourced information. From the viewpoint of system architecture, introducing the geographic database allows us to test various interface/ information technologies independently.

GeoLink currently holds 5400 pages that we collected on public spaces including restaurants, shopping centers, hospitals, temples, schools and bus stops. Figure 5 (a) shows the results of locating pages on the map. We can see how Web pages (restaurants, schools, temples, shopping centers, etc.) are distributed throughout the city. After digital cities become popular, people will directly register their pages in geographic databases, but until then, we need some technology to automatically determine the X-Y coordinates of each Web page. Kyoto is, however 1200 years old, and there are various ways to express the same address; this makes the process very complicated.

GeoLink uses a new data model called *augmented WEB space*. As shown in Figure 5 (b), the augmented Web space is composed of conventional hyper links and *geographical links*. A typical example of a geographical generic link is "within 100 meters." The link is called *generic*, because it is created according to each query

issued by users. Suppose the query “restaurants within 100 meters from the bus stop” is posed. The links are virtually created from a Web page for the bus stop to those of restaurants located within 100 meters. Efficient query processing methods for the augmented Web space have been developed.

Real-time sensory information includes bus schedules, traffic status, weather condition, and live video from the fire department. In Kyoto, 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 every few minutes. Such dynamic information really makes our digital city live. The first trial collects real-time bus data and displays them on the digital city.



(a) GeoLink (By Kaoru Hiramatsu) (b) Augmented Web Space

Fig. 5. GIS to Integrate Information

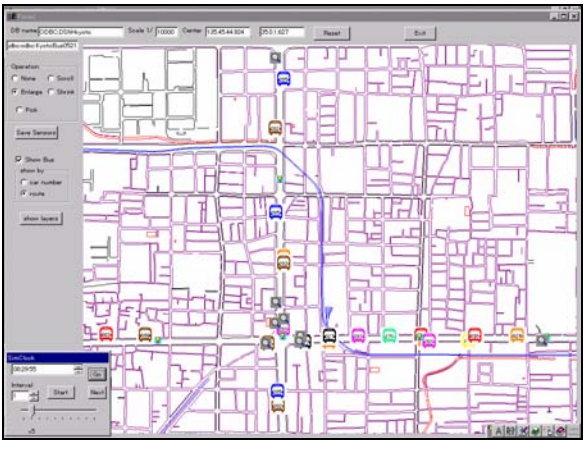


Fig. 6. Bus Monitor (By Yasuhiko Miyazaki)

Figure 6 shows a bus monitor developed by NTT Cyber Solutions Laboratories. Buses in the city run on the Web in the same manner as in the physical city. Real-time city information is more important for people who are acting 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 a restaurant, and what is on sale at the department store close to them. We can provide live information to mobile users through wireless phones.

3.3 Interface Layer

An enormous amount of information can be accessed through the Internet. Humans have never before experienced any similar expansion in terms of scale and speed. People's various activities are being recorded in the semi-structured database called the Web over time. Consequently, it might be possible to visualize human activities and social interaction, which cannot be directly measured, by investigating the information collecting on the Internet.

In GeoLink, the latitude and longitude of a shop are determined from its Web page address and a link is placed on the map accordingly. As information in the Internet increases, downtown areas will be gradually visualized on the map. We can "feel" the activities in the town from the map showing restaurants, schools, hospitals, etc. Observing this map over several years will enable us to understand the growth of the town. It is important that this observation can be carried out by anyone. A map of a digital city is not just a database to measure distances or to check addresses. A map will become a new interface that helps us understand the activities of the city.

Similarly, the three dimensional (3D) graphic technology will become a key component of the *interface layer*, when used in parallel with 2D maps. Providing 3D views of a digital city allows non-residents to get a good feel for what the city looks like, and to plan actual tours. Residents of the city can use the 3D interface to pinpoint places or stores they would like to visit, and to test walking routes. Fig. 7(b) shows a 3D implementation of Shijo Shopping Street (Kyoto's most popular shopping street).

(a) Sample View of 3D Kyoto

(b) 3D Shopping Street with GeoLink

Fig. 7. 3D Kyoto (By Stefan Lisowski)

We use 3DML (http://www.flatland.com), which is not well suited to reproducing gardens and grounds, but has no problem with modern rectilinear buildings. 3DML

was originally used to make it easy to construct games. We applied this tool to the development of 3D cities, since it makes us easy to build a town. A 3DML city can be basically understood as a city made of building blocks. For a start, we use a digital camera to take photos of the city. Some correction is needed in Photoshop, since it is inevitable that the upper parts of buildings appear smaller due to perspective. The next step is to pile blocks up to create the buildings and paste the appropriate photos. Although this requires patience, technical knowledge of virtual reality is not necessary. However, we cannot expect a precise 3D space like those produced by virtual reality professionals; it is more a tool for non-professionals.

Fig. 8. Kobe City after the 1995 Earthquake (By Stefan Lisowski)

Figure 8 shows a reproduction of Kobe right after the earthquake in 1995 created using existing photos. This work was requested by the Kyoto University Disaster Prevention Research Institute, which houses 15,000 photos taken of the Kobe area. The organization tried to display the photos on the Web, but the result was not easy to look through. By rearranging the photos in a 3D space, the data could be used in various ways. It was not easy to reproduce buildings from the photos, but we were able to reproduce one part of the city. In performing this, we realized that reproducing a 3D virtual city from photos or videos is an attractive approach. We currently have two approaches to building a 3D space: modeling it with CAD and reproducing it from photos or videos. 3DML can be seen as a tool that combines the two approaches while giving us the pleasure of personal creation.

3.4 Interaction Layer

Social interaction is an important goal in digital cities. Even if we build a beautiful 3D virtual space, if no one lives in the city, the city cannot be very attractive. We plan to use cutting-edge technologies to encourage social interaction in Digital City Kyoto. Katherine Isbister, a social psychologist from Stanford University, hit on an interesting idea. To encourage intercultural interaction in digital cities, she implemented a digital bus tour for foreign visitors. The tour will be an entry point for foreigners to the digital city, as well as to Kyoto itself. The tour has been implemented within the Web environment using I-Chat and Microsoft's agent

technology (see Figure 9). The tour guide agent will lead the visitors, who can interact in many ways, through the Nijo Castle in Kyoto simulated using 3DML.

Kyoto city, as the owner of Nijo castle, allowed us to take photos of the inside of the castle. The 3DML world created from those photos is so beautiful that nobody would believe the work was done by non-professional photographers. To prepare for creating the tour guide agent, Isbister participated in several guided tours of Kyoto. She noticed that the tour guides often told stories to supplement the rich visual environment of Kyoto and provided explanations of what Japanese people, both past and present, did in each place [6].

This system includes two new ideas. One is a service that integrates information search and social interaction. Unlike Web searches, which are solitary tasks, the digital bus tour creates an opportunity for strangers to meet. Another is to embody social agents that perform tasks for more than one person. Unfortunately, this agent cannot understand the contents of conversations at this stage. After this experience, however, we have developed a virtual city platform FreeWalk [18,19] and a scenario description language *Q* [10]. In the near future, agents will participate in the conversation of tourists on the bus and become famous as bus guides in the Internet world. Guide agents will stimulate various ideas about future digital cities.

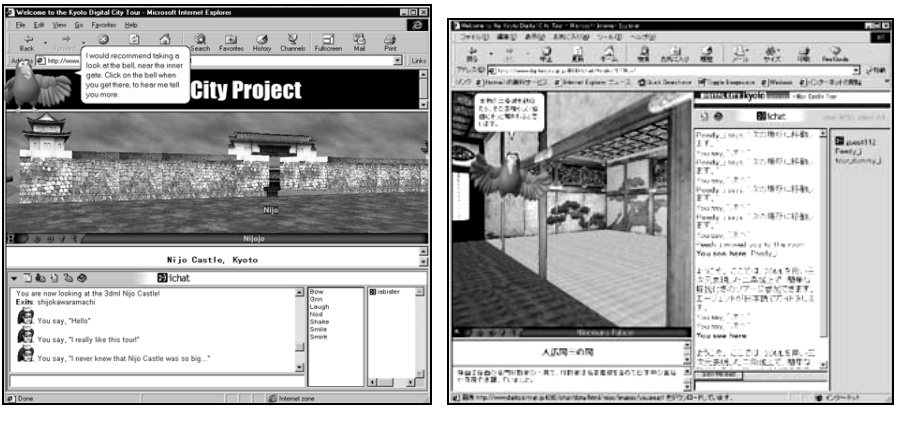


Fig. 9. Digital Bus Tour with Agent Guide (By Katherine Isbister)

3.5 Lessons Learned

We have learned important technologies for digital cities and future research directions from the experience of Digital City Kyoto.

1. *Technology for information integration* is essential to accumulate and reorganize urban information. Digital cities typically handle Web information and real-time sensor-based data from physical cities. Voluminous high quality digital archives can also be accessed through digital cities. The idea of “using a map” is commonly observed in digital cities. In this case, technologies are needed to integrate different kinds of urban information via geographical information systems (GIS). It is also necessary to introduce a technology to handle photos and videos of the city so as to

understand its activities. Great numbers of sensors embedded in the city will collect visual information automatically. These infrastructures will make 'sending and receiving information' in everyday life much easier.

2. *Technology for public participation* is unique to digital cities. To allow various individuals and organizations to participate in building digital cities, the entire system should be flexible and adaptive. For designing a human interface that supports content creation and social interaction, a new technology is required that encourages people with different backgrounds to join in. *Social agents* can be a key to encouraging people to participate in the development and life of digital cities. So far, most digital cities adopt the direct manipulation approach to realize friendly human-computer interactions. Social agents are used to support human-human interaction. The direct manipulation approach allows users to explicitly operate information objects. Since social agents (human-like dog-like, bird-like and whatever) will have the ability to communicate with humans in natural languages; users can enjoy interacting with the agents and access information without explicit operation. This allows a digital city to keep its human interface simple and independent of the volume of stored information [14].

3. *Technology for information security* becomes more important as more people connect to the digital city. For example, it is not always appropriate to make links from digital cities to individual homepages. We found that several kindergartens declined our request to link them to the digital city. This differs from the security problem often discussed for business applications, where cryptography, authentication and fire-walls are major technologies. Just as we have social laws in physical cities such as peeping-tom laws, digital cities should introduce social guidelines that provide the security people need to feel comfortable about joining the information space.

4 Collaboration with Other Digital Cities

The concept of digital cities is to build an arena in which people in regional communities can interact and share knowledge, experience, and mutual interests [11]. Digital cities integrate urban information (both achievable and real-time) and create public spaces in the Internet for people living/visiting in/at the cities. Each digital city has its own goal. Digital City Amsterdam [2, 3] is intended to provide a public communication space to people living in the city. Helsinki [13, 14] plans the next generation metropolitan network. In Kyoto, various new technologies are being developed for a social information infrastructure. Urban planning in which community members can directly participate in the design process is another motivation behind digital cities.

Unlike the conventional telephone network, there is no centralized control mechanism in the Internet. Even the power of governments cannot stop the flow of information. Anyone such as a politician, scholar, businessperson and student has equal access to the enormous store of information. Instead of huge hierarchical organizations, a knowledge network of small organizations or individuals covers the world. Unlike conventional mass media, the Internet allows us to directly contact thousands of vivid instances. While mass media filters collected information, refines and edits them, the Internet is a huge depository; it simply accumulates original

instances. For example, children who want to be music conductors can find plenty of information not only about famous conductors but also about other children in foreign countries with the same dreams.

To gain a better understanding of the big picture of digital cities on the Internet, we held international meetings on digital cities in 1999, 2001, and 2003. We invited people and papers representing their activities from cities including Amsterdam, Antwerp, Bristol, Helsinki, Seattle, Shanghai, Oulu, Turin and Vienna. We learned that each digital city has developed or is developing an information space that reflects its own cultural background. Since it is not realistic to standardize those activities, collaboration among digital cities becomes interesting. For example, a tool to traverse related cities is useful. Machine translation and conversational agents will be a great help in traversing digital cities. With such tools, cities that are geographically remote and that have different cultures will be brought closer together.

During this project, we found that digital cities have many directions including tourism, commerce, transportation, urban planning, social welfare, health control, education, disaster management, and politics. Digital cities attract people because different types of expertise contribute to building a richer city, and provide people with opportunities to create a new public space for their everyday life.

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