C-MAP: Building a Context-Aware Mobile Assistant for Exhibition Tours

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Abstract. This paper presents the objectives and progress of the Context-aware Mobile Assistant Project (C-MAP). The C-MAP is an attempt to build a personal mobile assistant that provides visitors touring exhibitions with information based on their locations and individual interests. We have prototyped the first version of the mobile assistant and used an open house exhibition held by our research laboratory for a testbed. A personal guide agent with a life-like animated character on a mobile computer guides users using exhibition maps which are personalized depending on their physical and mental contexts. This paper also describes services for facilitating new encounters and information sharing among visitors and exhibitors who have shared interests during/after the exhibition tours.

1 Introduction

This paper presents the objectives and progress of the Context-aware Mobile Assistant Project (C-MAP) [1–3]. The C-MAP is an attempt to build a tour guidance system that provides information to visitors at exhibitions based on their locations and individual interests.

Our long-term goal is to investigate future computer-augmented environments that enhance communications and information sharing between people and knowledgeable machines. The introduction of computer and network technologies into human communications is expected to enable us to go beyond temporal and spatial distributions. Stefik [4] has proposed the notion of a new knowledge medium, which is a kind of information network with semiautomatic services for the generation, distribution, and consumption of knowledge in our society. We believe that the consideration of computer networks that include humans as knowledge media will reveal the future form of Human-Computer Interaction (HCI). The knowledge media include environments for the collaboration of humans and machines, where software acts not as a passive tool but as an autonomous and active machine agent.

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In order to investigate how to create such a knowledge medium, we have chosen museums and open house exhibitions as our research laboratories. These are places where knowledge is accumulated and/or conveyed, and where specialist exhibitors provide knowledge to visitors with diverse interests and viewpoints[1]. Actual exhibitions, however, have many restrictions. For example, exhibitors are unable to display all of their collected material due to temporal and spatial restrictions, all visitors are unable to receive individual explanations from exhibitors, all visitors are provided with the same information prepared beforehand, and the one-way communication flow from the exhibitors to the visitor is often limiting. As a solution, recent computing technologies, such as mobile computing, are expected to remove many of the restrictions preventing natural two-way communications between exhibitors and visitors. At this time, we believe that the mediation of real objects in actual exhibitions is inevitable for knowledge sharing, even in the forthcoming digitized society.

The main goals of the C-MAP are as follows:

(1) To provide visitors touring exhibitions with information based on temporal and spatial conditions as well as individual interests, and
(2) To provide users with onsite and offsite services through the Internet (online exhibit information and communications support between exhibitors and visitors in combination with onsite services)[2].

The first goal will involve an approach to facilitating communications mediated by real objects by augmenting real environments with computing technologies [6]. The second goal will aim at implementing communications support between exhibitors and visitors in the long run.

Both goals are expected to enhance human communications distributed temporally and/or spatially. One characteristic of our approach is a mutual augmentation between two spaces, i.e., the information space and the real space. That is, the information space with guide services will reinforce tours in the exhibition (real space), and conversely, tours in the exhibition will provide users with motivation and focal points for communication beyond the existing temporal and spatial restrictions.

2 Related Work

The Cyberguide [7] is another attempt at providing a tour guide system. The authors of the Cyberguide proposed the concept of context-aware mobile applications, and prototyped a system that is able to provide users with location-sensitive information on exhibition site maps displayed on portable PCs. Although the technologies used in the Cyberguide and the C-MAP are similar,

[1] Kadobayashi [5] has discussed this in detail.
[2] In this paper, we call services provided at exhibitions “onsite services”, and services provided through a network before and/or after exhibition visits “offsite services”.

there are two big differences. First, the context-awareness achieved by the Cyberguide can only detect the user's location, i.e., physical (temporal and spatial) context. In contrast, we focus on capturing and utilizing the user's interests (mental context) as well. In the C-MAP system, two maps which visualize the geographical and semantic information of the exhibition space are used for showing exhibit information to the user, capturing his/her interests, and providing personalized information based on his/her individual context. Second, the C-MAP introduces an interface agent which mediates interactions between the system and the user. The interface agents have a life-like appearance, with animated characters. Residing in the mobile assistants, they draw the user's attention to information provided by the system, and show messages according to situations.

The Ubiquitous Talker [8], which consists of an LCD display and a CCD camera, allows users to view real objects (exhibits in our case) with related superimposed information by attaching color-bar ID codes to the objects. It also allows speech interaction, and hence, the users feel as if they are speaking with the objects themselves. The authors of the Ubiquitous Talker intend to demonstrate the augmentation of real space with information space, which we are also interested in. However, one of the goals of our system is to facilitate person-to-person interaction, e.g., new encounters based on shared interests and information exchange, as well as person-to-exhibit interaction. Our feeling is that the people behind each exhibit are knowledgeable and interested in this. The exhibit is a focal point for particular communities and guide agents should help visitors become part of them, if appropriate. In the C-MAP, we intend to increase mutual awareness among people having shared interests by providing them with information on exhibitors and visitors who share similar interests on the exhibit as well as information on the exhibit itself.

The ICMAS-96 Mobile Assistant Project [9] was an attempt to support communities that share certain interests by using mobile technologies. The project provided portable digital assistants with various services to assist conference attendees. The users could use e-mail and online-news services. They were also able to use the InfoCommon [10], which supports the exchange of information related to the conference, and the Community Viewer [11], which supports the formation of communities. The latter two applications were pioneering attempts at community support. Communities do not share clear goals and tasks like groups do, but often have wide interests. Therefore, community formation and communication hold the dynamics of a collaborative kind of creativity. Hence, community support research has been attracting many computer scientists recently [12]. In the ICMAS project, however, network communications was made possible by cellular phones, so the users themselves were responsible for connecting to the network to use services, and the servers could not provide spontaneous services. In contrast, the C-MAP system uses a wireless radio LAN to connect portable PCs. The constant, high-speed access allows servers to spontaneously provide information based on the current situation, and the users' portable PCs are able to communicate in real time. Moreover, for community support, providing only onsite services during the conference is insufficient. Accordingly, the C-MAP

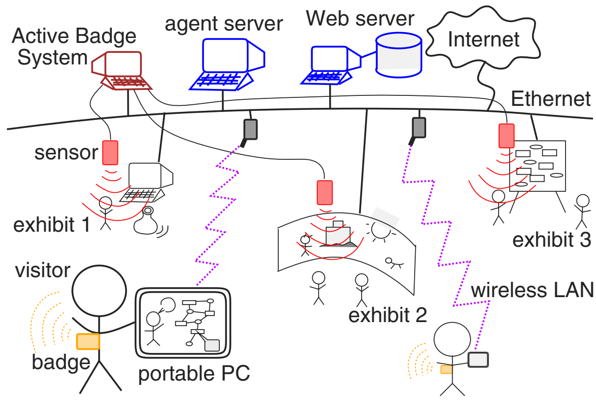

Fig. 1. Schematic diagram of C-MAP system

system uses the Web as an infrastructure for system development, enabling its services to offer offsite services.

3 C-MAP System

3.1 Hardware Architecture

We prototyped a mobile assistant at a two-day open house exhibition held by our research laboratory. **Fig. 1** illustrates the hardware architecture of the system. The system principally consists of servers providing exhibit-related information and guide information, and portable PCs connected with the servers by a wireless LAN.

We use Windows95 PCs with 32MB of RAM, i.e., fifteen Mitsubishi AMiTYs with pen-based interface and fifteen Toshiba Librettos with keyboards. To connect these PCs to the servers, we use a 1.2GHz radio wireless LAN (WaveLAN) that allows 1Mbit/sec communications.

The Web server is used as a server of Java applets for the mobile assistant, and as a server of Web pages related to the exhibits.

Olivetti's Active Badge System (ABS) [13] is used for user location detection. The ABS server has many sensors at the exhibit sites, to detect the locations of the users by infra-red linking to the badges that they wear. The server gathers the latest sensor data and updates the location data of all users. The sensors can detect badges within a 1 to 2 meter perimeter.

The agent server provides guidance, such as route planning and exhibit recommendation, by monitoring the ABS information and each user's interaction with the system on the portable PCs. The guide agent for each portable PC, which runs on the agent server, processes the personalized guide according to the user's context and displays the result on the portable PC. Therefore, thirty guide agents (equal to the number of PCs) at most run simultaneously on the agent server. We use SGI's Onyx with four processors and 128MB of RAM for the agent server. The servers and the portable PCs connect via the LAN, which further connects with the Internet, and is therefore open to the outside. This facilitates the collection of content and guidance material from the outside, and the provision of offsite services.

Note that since most exhibits demonstrated computer applications at our open house, the exhibit applications were able to share information with the mobile assistant servers by the LAN. Consequently, for example, exhibitors were able to provide highly personalized demonstrations by using the personal data (e.g., personal interests, touring histories, profiles) accumulated in the guide agent server.

3.2 Prototyping the Mobile Assistant

Overview of the Mobile Assistant Each portable PC runs the HotJava browser[3] for Java applets to guide the tour, show exhibit-related information, interact with the user, and display the animated characters of the guide agents.

Examples of a portable PC's display are shown in **Fig. 2** and **Fig. 3**. Both displays have a main window on the right and a frame on the left. The user obtains visual guidance of the exhibition space in the main window by alternatively viewing a physical map applet (**Fig. 2**), which displays the geographical layout of the sites, and a semantic map applet (**Fig. 3**), which visualizes the semantic relationships between the exhibits. The controlling frame displays links for viewing the two applets and the animated character and message box of the personal guide agent.

To provide the user with a personalized guide, we need to personalize the mobile assistant on the portable PC in some way. However, putting an individual's data into a portable PC just before he/she begins the tour is undesirable because the thirty portable PCs are used by many visitors. Instead, we install only the HotJava browser on each portable PC and put all of the information into the servers, e.g., the HTML file loaded by the browser, Java applets, guide agent server programs, and individual data dynamically obtained during the tour. First, data for identifying an individual PC and its user (badge ID) are written in the HTML file automatically generated at the reception. Second, the HTML file is loaded by the browser onto the PC, and finally, the agent applet started on the browser registers itself to the agent server.

We next explain the two guidance applets of the exhibition space and the personal guide agent provided on each portable PC.

Visualization of Exhibition Space: Physical Map and Semantic Map The principal function of the mobile assistant is guidance based on the visualized

[3] Since we needed to use the latest JDK1.1 to utilize the facilities of network communication and Japanese processing, HotJava was the only web browser able to support the JDK1.1.

Fig. 2. Screenshot of the mobile assistant display showing a physical map

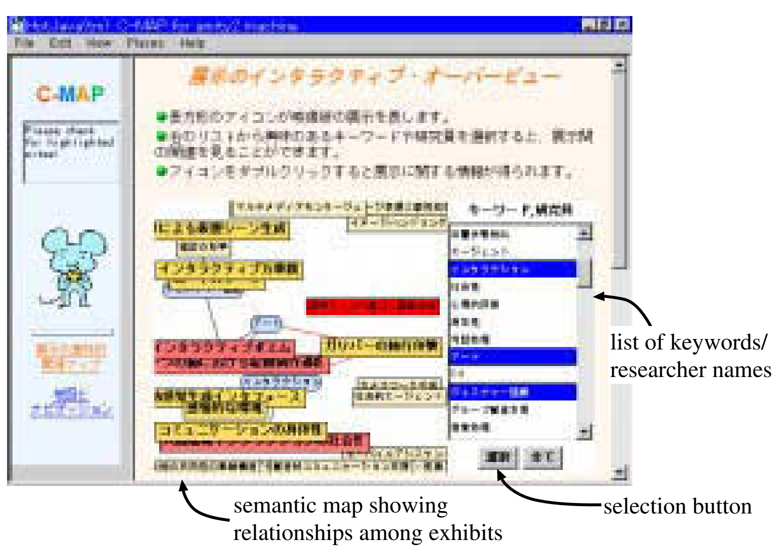

Fig. 3. Another screenshot showing a semantic map

exhibition space. This provides the user with the whole view of the exhibition space involving two aspects, i.e., a geographical map of the exhibition sites and a visualization of the semantic relationships between the exhibits. We believe this complementary guidance helps the understanding of the visitors during the tour because visitors tend to lose the overall view of the exhibition after visiting several of the individual exhibits, viewing demonstrations, and/or speaking with exhibitors (researchers).

The physical map shown in **Fig. 2** displays a two-dimensional view of the exhibition floor. This map provides the locations of exhibit sites (19 in our open house) and the posters (about 70) at the sites. A user can view short explanations by moving the mouse pointer to site/poster marks on the map. The map also shows the user his/her current location as another color mark by using the ABS data.

The semantic map shown in **Fig. 3** displays the graphical relationships between exhibits. The rectangular icons in the graph signify exhibits and the oval icons signify keywords and researchers (exhibitors). The keywords are technical terms characterizing the contents of the exhibits, which were previously extracted from outline texts prepared by the exhibitors. The semantic map provides the user with graphs having links between exhibit icons and keyword/researcher icons; this helps the user connect the fragments of knowledge.

However, because the keyword/researcher icon total is 75, a graph including all of these does not provide useful visualization. Therefore, we have adopted a display method with only the keyword/researcher icons selected by the user based on his/her interests. As a result, the graph of the semantic map can be structured based on the individual user's interests. For example, if the user selects the keyword "art", he/she can view a partial graph formed with only "art"-related exhibits. If the user selects other keywords, the semantic map restructures the graph based on the corresponding viewpoint.

What keywords the user selects affects the restructuring of the semantic map and the guide agent's recommendation of exhibits as well. Whenever the user pushes the keyword selection button, an interest vector[4] that quantifies the user's interests is sent to the agent server, and the personal guide agent calculates a new recommendation with the current interest vector of the user. In addition, this interest vector can be used to support meetings between visitors and exhibitors based on their current and previous interests.

The reason why we adopt this approach is due to our previous research [14, 15], which showed us that personalizing shared information based on individual viewpoints and exploiting the results can facilitate mutual understanding and information sharing between people with similar interests. To accomplish this task, we visualize the structure of the information space. In [14, 15], we visualize the information space structure of a set of texts by adopting a statistical method for quantifying the texts with weighted keywords as multivariate data, and we then compose two-dimensional metric spaces with two principal eigenvectors

[4] An interest vector is a multi-dimensional keyword vector, which is a sequence of 0 and 1.

of the data. However, with the mobile assistant used in tours, each and every user requires simple use and results that are easy to understand. Accordingly, we adopt another method to visualize the semantic structure of the exhibition space, by linking icons together and simulating dynamic behaviors with a simple spring model.

To provide the user with an overview of the exhibition, the semantic map displays all of the exhibit icons including those with a keyword not selected by the user. However, the semantic map displays exhibit icons having selected keywords with a larger size and more conspicuously, and in contrast, displays exhibit icons having non-selected keywords with a smaller size.

By double-clicking the exhibit icons, the user can view popup windows with a short explanation of the exhibits, and there are links to Web pages of research projects related to the exhibits.

Guide Agent: Recognition of User Situation, Exhibit Recommendation, Agent Character We have designed a personal guide agent that provides its user with personalized guidance in an exhibition. The guide agent calculates the user's mental context, processes the tour guidance by capturing his/her temporal and spatial context with the ABS information, and monitors the interaction between the user and the mobile assistant. The internal process of the guide agent is performed in the agent server and it is started for each portable PC, basically, for the user of the mobile assistant.

We prototyped the task of exhibit recommendations based on some user contexts, for spontaneous guidance by an agent. Several criteria were used for the recommendations, e.g., the similarity between the interest vector described in the previous section and each exhibit's keyword vector, the touring histories of users, the geographical distances between exhibit sites and user locations, the exhibit site attendance, and the exhibit demonstration schedule. The calculation of a recommendation responds to changes in the contexts, e.g., a user's selection of keywords on the semantic map and the user's movement to different exhibit sites. Recommended exhibits are indicated to the user by the highlighting of three icons (with higher scores) on both the physical and semantic maps.

The guide agent must interpret the primitive information obtained from the ABS to detect the user's movement through the exhibition sites and to generate individual touring records. The ABS server gathers badge IDs detected by the individual sensors every ten seconds or less. When the guide agent notices that a certain sensor successively detects the same badge, it interprets only one detection as "cruise", two detections as "enter", and more detections as "stay". Accordingly, when a user's badge is successively detected twice by a sensor located at a certain exhibit site, the guide agent decides the person has entered the exhibit site. When detected three or more times, the agent decides it is a visit and then records the time of the visit for the touring record.

One characteristic of our guide agent is the life-like character residing in the mobile assistant. It plays a role in the interaction between the user and the mobile

Table 1. Determination of agent motion and message according to internal state

Internal state	Action	Message
Recommendation	Suggesting	"Please check for highlighted sites!"
In calculation	Thinking	"Please wait. I'm thinking."
Urging to move	Hurrying	"Please hurry to the next sites!"
(No guide)	Idling	Random messages

Random messages: "How is it going?"
"I hope you are enjoying yourself!"
"Double click on the Semantic map for further information!"
"Click on the Map to zoom!"
"Move onto the site on the Map for a short overview!"

assistant and represents its internal state. The agent character is presented by an animated applet using GIFs with a text message box. Its roles are:

- To express the internal state of the guide agent with the animated character behaviors,
- To draw the user's attention to the results of the exhibit recommendations shown in the maps,
- To hurry the user to the next site if he/she appears to be using up too much of the tour time[5], and
- To inform the system usage by messages and encourage the use of the system.

Table 1 shows the correspondence of the guide agent's internal state with its behaviors and messages. We have prepared four actions for each animated character, i.e., suggesting, thinking, hurrying, and idling, and several corresponding messages. The guide agent switches these actions and messages according to its internal state. When it is idle, it displays messages for basic system usage in a random order.

4 Public Experiment and Evaluation

4.1 Outline of the Experiment

Using our annual open house held November 6th and 7th, 1997, we carried out a public experiment on the first version of the C-MAP system by setting up a reception booth for use of the mobile assistants at the entrance of the exhibition floor. The exhibition space consisted of five rooms. **Fig. 4** shows snapshots of the open house.

For a total of ten hours on the two days, approximately 170 users were registered for use of the mobile assistant. The static data of the users (names, affiliations, and so on) were recorded into a database at the time of user registration. After that, the host name of the portable PC, badge ID, and guide character[6] selected by the user were registered to generate the personal guide

[5] Because of the limitation of the portable PC's battery, we set a time limit of two hours for the guide service.

[6] We prepared eleven kinds of characters for the guide agent.

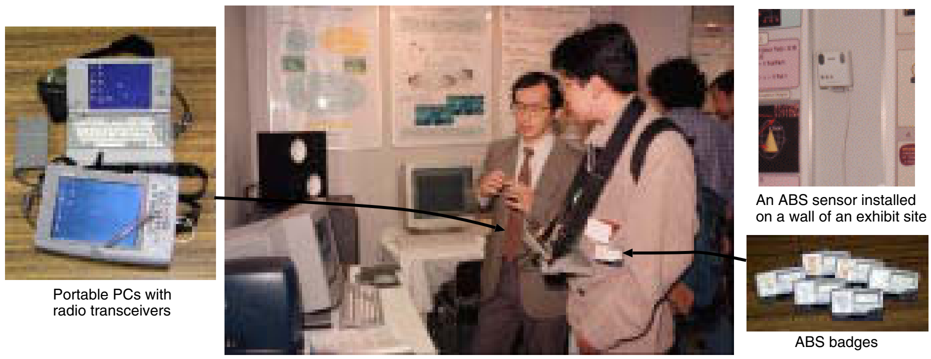

Fig. 4. Snapshots of a public experiment

agent. For first-time users of the system, we prepared three model courses of the tour to determine the default values of their interest vectors. Moreover, we tried to lighten the burden imposed on the receptionists by preparing desktop PCs which would let each of the visitors do the user registration by himself/herself and preview the exhibition by using the semantic map. The exhibition floor held nineteen exhibit sites and approximately seventy posters. The scale was appropriate for a 1 to 2 hour tour. We set up thirty ABS sensors on the walls of the exhibition site.

4.2 Evaluation of the Mobile Assistant: What Worked and What Didn't

The prototyped mobile assistant runs with the cooperation of several distributed sub-systems. Below, we summarize the parts which worked properly and those that did not.

- The procedures for user registration, preparation of the mobile assistant, and battery replacement (for the portable PCs) at the reception booth went smoothly. Although these procedures were done by receptionists unrelated to the system development, there were no errors in initiating the use of the mobile assistants.
- Each of the applets, i.e., the semantic map, the physical map, and the animated character, performed well.
- The exhibit recommendations by the guide agent were simple yet functional. The interest vector from the semantic map was properly used for the calculation of each recommendation.
- The ABS did not work as advertised by Olivetti as it was incapable of monitoring more than six sensors. Due to this complication, we had to limit our experiment using the location data of users for six demonstration sites inside one room.

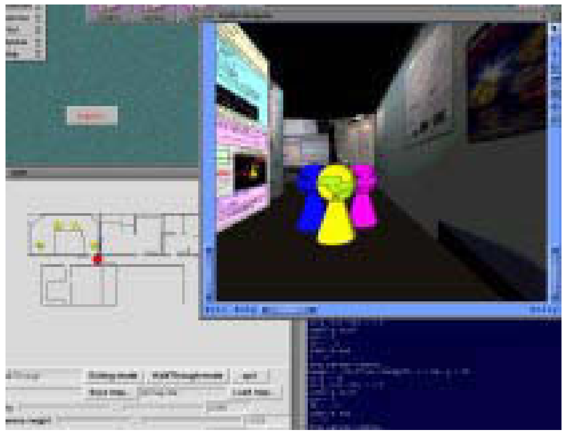

Fig. 5. Prototyping a virtual exhibition space including user avatars

- The guide agent did not use any location information for the exhibit recommendations because the ABS did not work properly.
- In the room with the ABS sensors, the location detection of the users was properly done. The location-aware services worked by displaying each user's current location on the physical map. However, badge detection by the sensors was unstable; sometimes a badge was not detected for a while after the user wearing it entered a new site.
- The animated character was able to display the different states of the agent with animation behaviors and text messages. However, the guide agent itself was not very complex so there were no states to display.

4.3 Combination with Exhibit Applications

As described at the end of Section 3.1, we can combine our mobile assistant with exhibit applications by allowing the applications to use the user information accumulated in the agent server. In this section, we show two examples.

Fig. 5 is an example of reproducing a virtual exhibition space with 3D graphics. This was accomplished by taking previous pictures of the exhibit sites and mapping these on the walls of the 3D space for texture. The 3D graphics were rapidly prototyped with an interpretive VR description language called InvenTcl [16] which is being developed at our laboratory. In the virtual exhibition space, there are avatar icons[7] of the current C-MAP users, which reflect the location information of these users by the C-MAP's agent server. By clicking on the avatar icons, one is able to view profile information of the users. Although this exhibit application was originally prototyped to lend appeal to the development

[7] Because we could not prepare users' portraits or illustrations, we mapped the illustrations of their agent characters on their avatar icons instead.

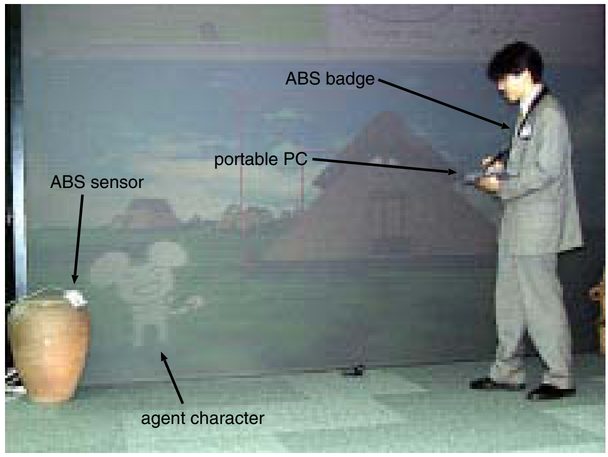

Fig. 6. Guide character appearing in an exhibit application

efficiency of the VR description language, the users could use it to determine whether remote exhibit sites were crowded or to obtain information for meeting other C-MAP users. At the beginning, we had thought of providing meeting support for the guide services, but we left its implementation out because of insufficiencies in the portable PCs to perform calculation and display. In fact, this application was accomplished by implementing and running a high-performance graphics computer, SGI's Indigo2. However, since we assume that such computer restrictions will be removed in the near future, we are continuing to examine how to provide such applications for mobile assistant services.

An attempt to personalize an exhibit demonstration according to personal user data obtained by the mobile assistant, is another combination example. **Fig. 6** shows an exhibit application where a user's personal guide agent character appears. This application is called VisTA-walk [17]. VisTA-walk is an experimental system being developed at our laboratory that will allow users to walk through and access information in 3D virtual spaces with gestures by using Computer Vision technology. Usually, the users of VisTA-walk explore virtual spaces alone. In this example, however, once a user's badge is detected by a sensor located in the demonstration area, the agent character residing in his/her mobile assistant automatically appears and leads the user in the virtual space of VisTA-walk. For a combination of exhibit applications with the mobile assistant, various directions are expected such as exhibit guidance personalization based on the individual interests and knowledge of the user, inferred by his/her previous touring records. This time, the user's frequency in using the mobile assistant was used to quantify the activity and (based on this value) to automatically switch the demonstration courses of VisTA-walk [18]. This personalization is simple but effective for increasing user satisfaction in experience-based demonstrations.

4.4 User Evaluation and Discussion

We asked the users to fill in a questionnaire about the usability of each function after use. In this section, we present a summary along with a discussion.

- The usability of visual guidance for the exhibition space with the semantic and physical maps was evaluated. The frequency of keyword selection on the semantic map, which can be regarded as a standard of user activity in our system, reached 3.7 times during the tour for an average of 84 users. More than 10% of the active users performed the keyword selection approximately ten times. Considering the inconvenience of the portable PC and the scale of the exhibition, this result seems to show the acceptability of the semantic map. We believe the semantic map is simple and easy to understand for all users; visitors, in fact, are generally eager to receive background information about the exhibits they attend.
- According to the evaluation, the users had a feeling of intimacy with the character of the guide agent. However, they did not think it was helpful for improving the agent's reliability and the representation of its internal state. If we consider the combination of the exhibit applications shown in the previous section, the appearance of the identifiable guide agent enhances the consistency of the entire guidance for the user.
- We received many comments that the portable PCs were heavy and hard to use. We therefore need to improve the portable devices, e.g., the separation of the user interface part from the computer itself, and the ubiquity of the interface devices in exhibition environments. This is an important future modification.
- We received many requests for voice guidance. Actually, it could be effective to use audio information together with visual information, especially when the guide agent provides spontaneous guidance.

5 Current Directions: Extending Offsite Services

5.1 Online View of Exhibit Information

In this section, we describe one of our current issues, i.e., enrichment of the services in the information space in order to facilitate deeper person-to-exhibit interaction and person-to-person interaction as well.

Although we had prepared links to Web homepages related to the exhibits on the semantic and physical maps, Web-surfing by users was rarely observed during the open house exhibition. This is understandable because, in general, users are not expected to search the Internet with such inconvenient PCs when the actual exhibits are in front of them. However, when we consider the provision of these applets as an offsite service, the semantic map is useful for providing homepages of projects in our research laboratory, and it is adaptive to restructuring according to the individual interests of users. Evaluation of such cases by publicly providing offsite services is our present focus.

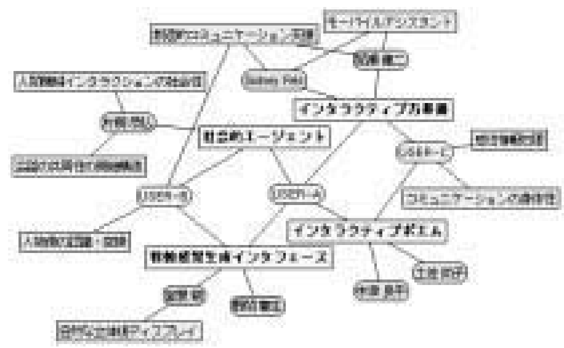

Fig. 7. Graphic view of a social network

Our mobile assistant can be used on Web browsers in remote sites because its user interface is built with Java applets. For example, although its development was not completed in time for the experiment, if we had released the semantic map before the open house it could have allowed potential visitors a preview of our research exhibition. This would have helped in the advance preparation of the personalized guide agents and in improving the exhibit.

Since the user data that can be obtained by the mobile assistant during a tour is limited, obtaining detailed user data such as user interests and areas of expertise by online services would be very beneficial. We are currently developing such an offsite service, i.e., an online viewing system based on question-and-answer interaction, which personally directs a user in exploring the information space of exhibitions [19].

5.2 Constructing Social Networks: Community Support

One of the main objectives of the C-MAP is to encourage human-to-human communications based on exhibitions. Namely, we aim to support communications among visitors/exhibitors sharing interests and knowledge concerning the exhibits.

Accordingly, we are planning to structure the records of mobile assistant users to provide them with social networks [20] that can be accessed by the Web. The social network's structure will be a graph whose nodes represent visitors, exhibitors, and exhibits and will have connections between people and exhibits according to their degree of attachment to exhibits[8].

Fig. 7 is a graphic view of the kind of social network which we are aiming for. We applied the semantic map applet to graph social networks by representing exhibits with rectangular icons and visitors/exhibitors with oval icons. The network in this example was constructed by placing a visitor, "USER-A", in the

[8] By *attachment to exhibits*, we mean exhibitors being involved in the exhibits and visitors being interested in them or spending much time to see them.

center. The exhibit icons which are directly connected to the "USER-A" icon are the exhibits in which he had deep interest. Beyond these exhibit icons, you can find other visitors and exhibitors, who are also deeply attached to the exhibits. Further beyond these visitor/exhibitor icons, you can find other exhibits, which other visitors/exhibitors are attached to.

The degree of attachment between visitors/exhibitors and exhibits might be determined by individual user data such as the interest vectors which we described before, profiles, touring histories, and so on. We expect offsite services, described in the last section, to capture more detailed data of individual users. In the example, we simply determined the degree by keyword co-occurrences between users' interest vectors and exhibits' keyword vectors, which were all of the quantified data we could capture during the open house exhibition. The selection of visitors to be shown in the network, which are related to "USER-A", was also determined by keyword co-occurrences between their individual interest vectors.

It is hoped that such a social network can be used to encourage new encounters between individuals and the formation of new communities based on their shared interests. For example, by viewing the social network, USER-A can easily notice the existence of exhibitors and other visitors, such as USER-B and USER-C, for exhibits which attract his interest.

Another expected effect of social networks is the social (collaborative) recommendation of exhibits. For example, the social network may encourage USER-A to visit exhibits which had not been noticed by him yet but had been deeply appreciated by USER-B, who shares many interests with USER-A.

The Thinking Tag [21] is well known as another effort to facilitate communication between humans sharing interests at places where many people gather. This is an electronic name tag that is capable of displaying the degree of agreement between the interests of two persons wearing the tags in a face-to-face encounter. Individual users' interests are quantified by means of questionnaires at the entrance to the party place. Compared with the Thinking Tag, the characteristics of our method are: The users do not have to face each other; the users can view shared information among them, which may be common ground for communication; and the social network can be dynamically reconstructed according to changes in the contexts of users and exhibition environments.

Practical issues for providing social networks are topics for future work, e.g., forms of provision, combination with other information resources, privacy protection against the public dispersal of individual information, and so on.

6 Conclusions

We have prototyped a mobile assistant that can personally guide visitors touring exhibitions based on their locations and individual interests. This mobile assistant was used as a testbed at our two-day open house. The usability of geographically/semantically visualized guidance was experimentally demonstrated. In addition, a personal guide agent that spontaneously recommends exhibits based on user context was demonstrated. We also proposed a novel style of exhibition, i.e., the personalization of exhibit demonstrations from user data obtained by the mobile assistant.

The characteristics of our project's targets can be summarized as follows:

(1) To extend the concept of context-awareness for exhibition guidance,
(2) To design a life-like agent that spontaneously guides a visitor,
(3) To facilitate communication in a community by the sharing of knowledge and interests related to the exhibition, and
(4) To extend the temporal and spatial view of exhibit-related services including offsite services.

Targets (1) and (2) were partially accomplished and offered material for the evaluation and discussion of such forms of HCI. Targets (3) and (4) have not been completed, but we have prepared an infrastructure for carrying them out.

Our system consists of many distributed sub-systems and users who work together cooperatively. In this system, communication and information sharing between people and knowledge-bases are mediated by machine agents that facilitate their knowledge conveyance and future association. This is an approach that shows one direction of the future HCI. Although the current version of the C-MAP system uses only a guide agent as a machine agent, we plan to design an agent that acts as an exhibitor, one that acts as an interface secretary for visitors, and one that acts as a mediating agent for all participants including these machine agents. This will involve human-to-agent communication as well as agent-to-agent communication and will have great relevance to recent multi-agent research.

Finally, we mention the distributed cooperation performed in the project. In this project, there were various collaborations among project members. For example, the system development involved the collaboration of approximately ten members. To collect content and combine the exhibit applications, we relied on the cooperation of close to fifty researchers in our laboratory. To carry out the public experiment, we relied on the cooperation of receptionists in the reception procedure. In order to achieve the above forms of cooperation, the infrastructure of the Web was indispensable. The Web facilitated the distributed development and flexible integration of sub-systems. The test results of the system integration showed the sharing of information as it was. This made it easy to manage the versions of the system. Moreover, we needed only to install a Web browser on each of thirty personal PCs, and hence, last minute changes could be easily integrated. We were able to use updated information provided by researchers to collect content involving exhibit-related information. All in all, this means our system of using the Web as an infrastructure consistently supports knowledge conveyance from specialists to visitors and, furthermore, it allows the communication form itself, of the people involved in an exhibition, to be changed.

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