Digital Guide Map Using Tiled Display and Recommendation Function

Tetsuro Ogi
Graduate School of SDM
Keio University
Yokohama, Japan
ogi@sdm.keio.ac.jp

Yoshisuke Tateyama
Graduate School of SDM
Keio University
Yokohama, Japan
tateyama@sdm.keio.ac.jp

Junichi Kawasaki
Graduate School of SDM
Keio University
Yokohama, Japan
junjo@z6.keio.jp

***Abstract*—In this study, digital guide map that uses the tiled display wall was constructed. In the digital guide map used in the shopping mall or shopping street, it is necessary to present the suitable information to the users who visit there without definite purposes. This study aims at constructing the effective digital guide map by combining the functions of presenting the high resolution large image and the effective recommendation. Especially, the recommendation algorithm that recommends the suitable items to the unidentified user in the public space based on the probability density distribution that is constructed from on the fragmentary usage history data was developed. And it was applied to the restaurant guide map to evaluate the effectiveness of this method.**

Keywords-tiled display wall; recommendation; digital guide map; probabilitydensity distribution

I. INTRODUCTION

Recently, digital signage has become popular according to the advancement of large screen display and network technology [1]. For example, in the shopping mall or the shopping street, the digital guide map is often used. However, a lot of digital guide map systems are not necessarily used effectively, because the user cannot access the necessary information efficiently. Therefore, the development of the advanced digital guide map that utilizes the human centered information communication technology is required.

In this study, the digital guide map that uses the tiled display wall was constructed. The tiled display has a feature that the high resolution large display can be constructed at a low price by placing several LCD monitors [2][3]. Then, this type of display can be expected to be applied to the digital guide map in the public space easily. Moreover, in order to use the digital guide map effectively, the method of transmitting the necessary information to the user is also important. This paper discusses the requirements for digital guide map, the architecture of the prototype system, the effective recommendation function, and the evaluation of the proposed system.

II. REQUIREMENT IN DIGITAL GUIDE MAP

In a lot of digital guide map systems, the information about the contents is stored hierarchically based on the attributes of the data. In this case, it is necessary that the user selects menu items many times in the hierarchical structure of the menu. For example, the user must select "restaurant", "Japanese food", and "Hiyoshi Soba", in order to access the target information in the hierarchical menu. When the purpose of the information retrieval is clear, the user can easily find the target information by using the hierarchical menu. However, when the user wants to get the information about the shop or the restaurant without any definite purposes, it is not easy for him or her to retrieve the target information by going up and down in the hierarchical structure of the menu.

This study proposes the method of presenting the list of all the information to the user who visits the shopping mall or the shopping street without definite purposes. In order to present the detailed information of all the items at the same time, the large and high resolution display is necessary. However, when a lot of information is displayed in the large screen display, it is difficult for the user to find the necessary information from the displayed contents. In order to solve this problem, the implementation of the recommendation function that selects the important items from the displayed information and highlights them is also required.

Therefore, in this study, the functions of the high resolution large display and the effective recommendation were implemented in the digital guide map system so that it can support the decision of the users who visit the shopping mall or shopping street without any definite purposes.

III. TILED DISPLAY WALL

As a high resolution large display used for the digital guide map, tiled display technology was introduced. Though the super high definition display such as 4K monitor can be used to represent the high resolution image, the tiled display has a feature that it can be constructed at a low price.

The tiled display wall that is used in this study is constructed using 4x3 LCD monitors as shown in Figure 1. Since Dell 2007FP (20-inch LCD, 1600x1200 resolution) is used for each monitor, the total resolution of this display is 6400x3600. Moreover, three graphics computers of Dell Precision T5500 which have two NVIDIA Quadro FX1800 graphics cards are used, so that each computer outputs four screen images respectively.

As for the middleware to render the synchronized image on the tiled display wall, SAGE (Scalable Adaptive Graphics Environment) is used [4]. Figure 2 shows the software architecture of rendering the image on the tiled display wall.

978-0-7695-4458-8/11 $26.00 © 2011 IEEE
DOI 10.1109/NBiS.2011.72

The information about the window size and window position of the displayed image is managed by Free Space Manager in the master node, and it is sent to the display nodes as SAGE Message. The application node also receives the message from Free Space Manager, and it sends the pixel stream of the application to the display nodes via the SAGE Application Interface Library (SAIL). In each display node, Display Manager renders the image on each monitor based on the received stream data. By using this mechanism, the synchronized high resolution image can be represented on the tiled display wall.

As for the application program that displays the guide map on the tiled display wall, Image Viewer that was developed using SAGE was modified and used. Since Image Viewer is constructed based on Image Magick, various image files can be loaded and they are transmitted to the display nodes as DXT format data. In this system, the function of Image Viewer was improved so that the image data can be displayed at an arbitrary size and an arbitrary position on the tiled display wall.

Figure 1. Tiled display wall used in this study.

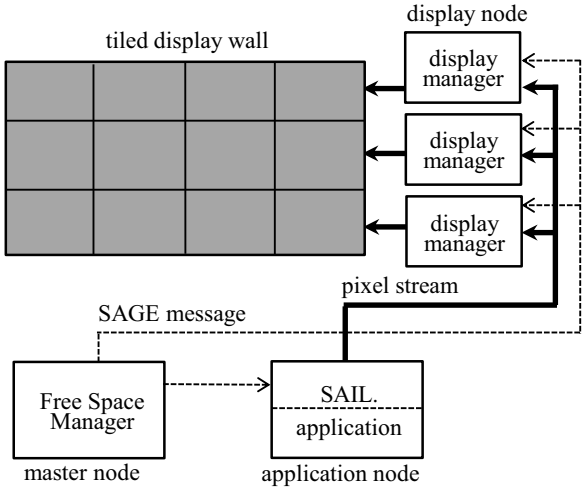

Figure 2. Software architecture of tiled display application.

IV. Recommendation Function

A. Basic Concept

Next, the algorithm of the recommendation function was examined. Currently, in the Web site of the electric-commerce such as Amazon.com, the recommendation function that proposes the commodities suitable to the user's interest is often used [5]. However, it is difficult to use the conventional recommendation method effectively in the public space such as the shopping mall or the shopping street.

The existing recommendation methods analyze the recorded usage history data based on the user's ID, and recommend the items that are suitable to the user's interest or preference. As for the recommendation method, various algorithms have been proposed. For example, the user-based collaborative filtering method calculates the similarities between users based on the usage history data [6], the content-based collaborative filtering method calculates the similarities between items based on the usage history [7], the content filtering method calculates the similarities between items based on the attributes of the items [8], and the hybrid collaborative filtering method combines both the collaborative filtering and the content filtering methods [9]. However, in these methods, it is necessary to collect a lot of usage history data based on the user's ID, because the similarities between users or items must be analized using the history data.

On the other hand, in the case of the digital guide map systems that are used in the public space, it is difficult to identify the user based on the user's ID. In addition, when several users act in a group, the characteristic of the group changes according to the members of it. Therefore, the user's behavior in the public space cannot be managed using the ID, and the accurate usage history data for each user cannot be recorded. In this study, in order to solve such a problem, the recommendation method that proposes the suitable items based on the probability theory using the fragmentary usage history data of the unidentified user or group was developed.

B. Recommendation based on Probability Theory

In the recommendation function introduced in this study, the probability density distribution of the similarity between items is expressed in the following form based on the fragmentary reference history data.

$$P(i,j) = n(i,j) / \sum_{j=1}^{N} n(i,j) \quad \ldots (1)$$

where i and j are items, $n(i, j)$ means the number of cases where item j is referred with item i, and $P(i, j)$ means the probability density of it.

Since the similarities between items change according to the purposes of the users, this method treats them based on the probability theory. This method does not analyze the similarity between items accurately based on the attributes of the items, but calculates the similarity as probability density distribution based on the fragmentary reference history data. Then, when the new usage data is added, the similarity probability changes.

In this method, the reference number between each item is calculated from the fragmentary reference history data, and in total, $N(N\text{-}1)$ reference number data are stored in the database as a table. From this table, the probability density distribution of similarity between items is generated based on the equation (1). Figure 3 shows the method of generating the data of the probability density distribution of the similarity.

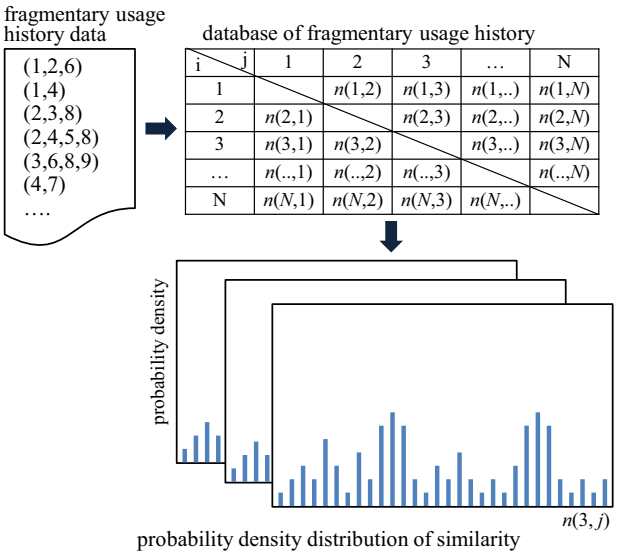

Figure 3. Generaion of probability density distribution of similarity

When the similarity between each item is expressed as the probability density distribution, the final probability density distribution for the recommendation can be calculated using the mathematical operation. For example, when the user is interested in both item of "a" and item "b", the probability density distribution of the similarity between "$a \wedge b$" and other item "j" is expressed using AND operation as follows,

$$P(a \wedge b, j) = P(a, j), if\,(P(a, j) < P(b, j))$$
$$P(a \wedge b, j) = P(b, j), if\,(P(a, j) > P(b, j)) \quad \ldots (2)$$

And the probability density distribution of the similarity between "$a \vee b$" and other item "j" is expressed using OR operation as follows,

$$P(a \vee b, j) = P(a, j) + P(b, j) \quad \ldots (3)$$

These operations are performed using the normalized probability density distribution. Figure 4 shows the method of these operations.

When the probability density distribution of the similarities between the user's interest and the other items is calculated, the suitable content can be recommended using several selection methods. For example, high-ranking selection is a method that selects item j according to the large order of the probability density $P(user's\ interest, j)$. On the other hand, probability selection is a method that selects item j for the recommendation based on random numbers that is generated according to the probability density distribution.

In the proposed recommendation method that is based on the probability density distribution, it is possible to recommend the suitable items to the user or user group who visits the shopping mall or shopping street for the first time and for whom there are no data of the usage history.

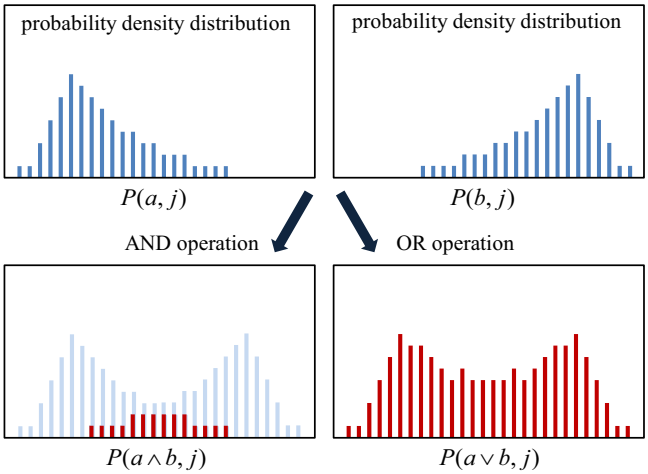

Figure 4. AND, OR operation based on probability theory

V. Experiment on Recommendation Method

A. Hiyosi Digital Guide Map

In this study, in order to evaluate the effectiveness of the proposed digital guide map system, the prototype of Hiyoshi Digital Guide Map that presents the information about the restaurants around Hiyoshi Station was developed [10].

In this system, information about one hundred restaurants, such as the restaurant number, restaurant's name, business hours, typical menu, price, telephone number, HP address, and photograph are presented on the map. Figure 5 shows the screen image of this system and Figure 6 shows the information of each restaurant displayed on the map. This system can display all the information of one hundred restaurants by using the high resolution large image on the tiled display wall. The restaurants that the user selects or the system recommends are highlighted by putting the marks on the photograph images.

When the user inputs the restaurant number that he or she is interested in by using a ten-key interface, the selection mark is displayed on the image of the selected restaurant. Next, the recommendation marks are also displayed on the images of the recommended five restaurants based on the above-mentioned recommendation algorithm as shown in Figure 5.

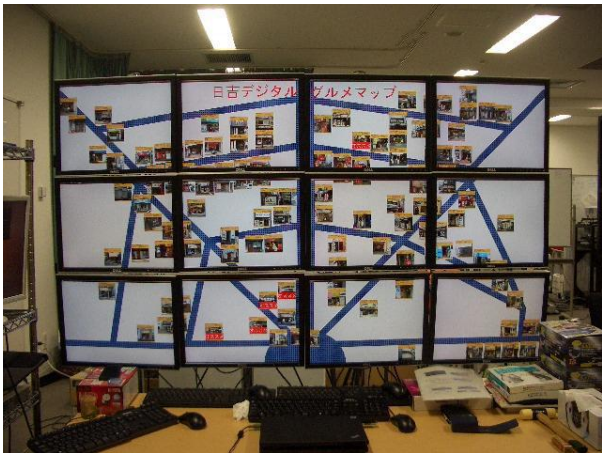

Figure 5. Screen image of Hiyoshi Digital Guide Map.

Figure 6. Restaurant inofrmation.

B. Recommendation Algorithm

Characteristics of various recommendation algorithms based on the probability density distribution were experimentally evaluated using Hiyoshi Digiral Guide Map.

First, in the experiment, the database of the fragmentary usage history data was constructed through the following process. The restaurant where the user wants to go would change according to the user's situations or the user's feelings. In this process, five kinds of situations such as "having lunch alone", "having dinner alone", "having lunch with friend", "having dinner with friend", and "having coffee" were assumed, and each situation was selected twice in random order.

Next, the subjects select five restaurants to which he or she want to go, by looking at the information on the digital map in each situation. In this case, in order to construct the database with diversity, the subjects were asked to select the restaurants in various feelings such as "want to eat noodles" or "want to eat fast food". The number of subjects was 10, and in total, 100 fragmentary usage history data were recorded.

After constructing the database from the fragmentary usage history data, the following preliminary experiment was conducted by using four kinds of recommendation algorithms, such as i) high-ranking selection from the probability density distribution made by AND operation, ii) high ranking selection from the probability density distribution made by OR operation, iii) probability selection from the probability density distribution made by AND operation, and iv) probability selection from the probability density distribution made by OR operation.

The subject inputs the restaurant number that he or she wants to go using the ten-key interface while looking at the information displayed on the digital guide map. The system selects one recommendation algorithm from four kinds of methods in random order, and puts the recommendation marks on up to five restaurants based on the subject's input. The subject again inputs the next restaurant number that he or she wants to go referring to the information of the recommended restaurants. Then, the system again puts the recommendation marks on up to five restaurants based on the subject's input. In the experiment, the input of restaurant number by the subjects and the recommendation of restaurant by the system were repeated three times.

In the experiment, the subjects were asked to answer the following questionnaire using five-grade system from 1 ("do not think so at all") to 5 ("think so very much") for each recommendation algorithm.

Q1. Was the interesting restaurant recommended?
Q2. Was the unpredictable restaurant recommended?

The number of subjects was 20, and the ages of the subjects were from twenties to fifties. Figure 7 shows the result of this experiment. In the graph, the averages and the standard deviations of the evaluation values are shown.

From the result, we can see the following tendency. When the evaluation value for question 1 was large, the evaluation for question 2 was small, and when the evaluation for question 1 was small, the evaluation for question 2 was large. This means that in the recommendation, the concordance and unpredictability to the user's interest are conflicting.

When AND operation was used to calculate the probability density distribution for the user's repeated inputs, there was not a significant difference between the evaluation values in the high-ranking selection and the probability selection, because the number of recommendation candidates of which the probability density was larger than 0.0 decreased. On the other hand, when OR operation was used to calculate the probability density distribution, there was significant difference between the high-ranking selection and the probability selection at 5% level. Namely, we can understand that when the high-ranking selection is used, the concordant recommendation to the user's interest is given, and when the probability selection is used, the unpredictable recommendation is given.

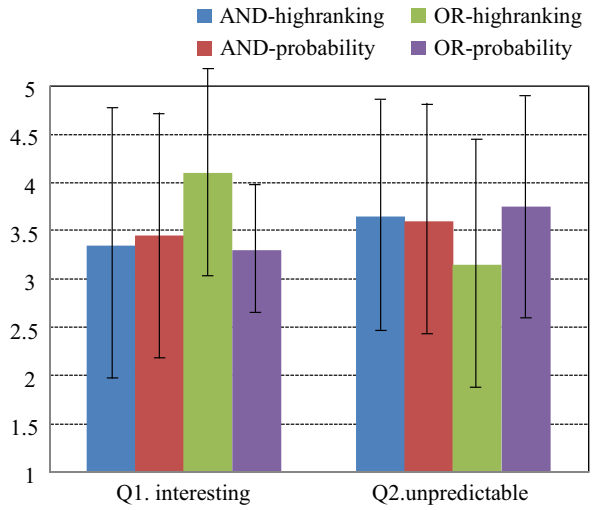

Figure 7. Result of preliminary experiment

C. *Proposed Method*

In the decision support system that is used by the user who doesn't have a definite purpose in the public space such as the shopping mall or the shopping street, it is desired that both the concordant and unpredictable recommendation is given to the user. Namely, it is important that the recommendation function can support the user to narrow down his or her interest by giving the concordant information as well as to expand his or her interest by giving the unpredictable candidates. Therefore, in this study, the recommendation method that combines the high-ranking selection based on AND operation that presents the concordant information and the probability selection based on OR operation that presents unpredictable information was introduced. In this method, when five restaurants are recommended, one restaurant is presented using the high-ranking selection based on AND operation and four restaurants are presented using probability selection based on OR operation.

In this study, the proposed combination method and the random recommendation method were experimentally compared. In the experiment, the system recommended five restaurants whenever the subject input one restaurant number that he or she is interested in. This process was repeated until the subject inputs three restaurant numbers. This experiment was conducted by using the proposed recommendation method and the random recommendation method. And the subjects were asked to answer the following questionnaires using seven-grade system from 1 (“do not think so at all”) to 7 (“think so very much”) after each experiment.

Q1. Was the interesting restaurant recommended?
Q2. Was the unpredictable restaurant recommended?
Q3. Was your interest narrowed by the recommendation?
Q4. Was your interest expanded by the recommendation?
Q5. Was this system useful for your decision making?

The number of subjects was 12, and the ages of the subjects were from twenties to thirties. Figure 8 shows the result of this experiment. In this graph, the averages and standard deviations of the evaluation values are shown. From the results of question 1 and question 2, we can see that the proposed method gave the concordant and unpredictable recommendation to the user. And the results of question 3 and question 4 show that this recommendation can support narrowing and expanding the user's interest, and it can be said that the proposed method is a well-balanced recommendation method between the concordance and unpredictability. Finally, by considering the result of question 5, we can understand that this method functioned effectively for the user who does not have a definite purpose to make a decision of selecting a restaurant.

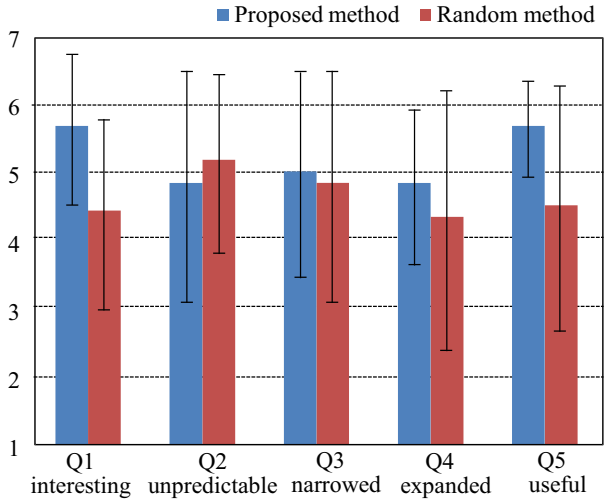

Figure 8. Result of evaluation experiment.

VI. Conclusions

In this study, the digital guide map using the tiled display wall was developed. In order to present adequate information to the user who visits the public space such as the shopping mall without a definite purpose, the functions of high resolution large display and the effective recommendation are necessary. Especially, the recommendation function based on the probability density distribution that was constructed from the fragmentary usage history data of the unidentified user was developed. In this case, it is important to present the unpredictable items that expand the user's interest as well as to present the concordant items that narrow down the user's interest. Therefore, in this study, the recommendation method that combines the high-ranking selection based on AND operation with the probability selection based on OR operation was proposed, and the effectiveness of this method was experimentally evaluated.

Though this experiment was conducted using 100 fragment data, it is necessary to evaluate the system using the increased number of fragmentary data, because the fragmentary data is increased according to the expansion of the use. Though the ten-key was used as an input interface of

the tiled display, the development of new interface such as the multi-touch interface is important, because the usability of the system influences the storage of the fragmentary data. Moreover, the guide system that uses the smart phone is recently researched. Future work will include developing the guide system that integrates the technologies of the large display and the smart phone.

ACKNOWLEDGMENT

This study was funded partly by Grant-in-Aid for for Challenging Exploratory Research 22650023 and supported by Keio University Global COE program (Center for Education and Research of Symbiotic, Safe and Secure System Design). And we would like to thank Hideaki Kuzuoka (University of Tsukuba) and Nobuyuki Kukimoto (Cybernet Systems Co. Ltd.) for their supports.

REFERENCES

[1] J. Harrison, A. Andrusiewicz, "An Emerging Marketplace for Digital Advertising Based on Amalgamated Digital Signage Networks," 2003 IEEE International Conference on E-Commerce Technology (CEC'03), pp.149-156, 2003

[2] N. Kukimoto, G. Fleury, J. Leigh, "Tiled Display System for Improved Communication Efficiency," 2010 International Conference on P2P, Parallel, Grid, Cloud and Internet Computing, pp.446-449, 2010

[3] Y. Ebara, Y. Shibata, "Study on Realistic Communication Technology with Tiled Displays Wall," 2009 International Conference on Network-Based Information Systems, pp.612-617, 2009.

[4] L. Renambot, A. Rao, R. Singh, B. Jeong, N. Krishnaprasad, V. Vishwanath, V. Chandrasekhar, N. Schwarz, A. Spale, C. Zhang, G. Goldman, J. Leigh, A. Johnson, "SAGE: the Scalabl Adaptive Graphics Environment," Workshop on Advanced Collaborative Environments, 2004.

[5] G. Linden, B. Smith, J. York, "Amazon.com Recommendations: Item-to-Item Collaborative Filtering," IEEE Internet Computing, Vol.7, No.1, pp.76-80, January, 2003.

[6] P. Resnick, N. Iacovou, M. Suchak, P. Bergstrom, J. Riedl, "GroupLens: An Open Architecture for CollaborativeFiltering of Netnews," ACM Conference on Computer Supported Cooperative Work, 1994.

[7] B. Sarwar, G. Karypis, J. Konstan, J. Riedl, "Item-based Collaborative Filtering Recommendation Algorithms," 10th International World Wide Web Conference, 2001.

[8] K. Lang, "NewsWeeder: Learning to Filter Netnews," 12th International Machine Learning Conference, 1995.

[9] M. Balabanovie, Y. Shoham, "Fab: Content-based Collaborative Recommendation," Communications of the ACM, Vol.40, No.3, Mar, 1997.

[10] J. Kawasaki, Y. Tateyama, T. Ogi, "Action Decision Support by Digital Guide Map Using Tiled Display," ASIAGRAPH 2010 in Tokyo, pp.105-106, 2010.