CONTEXT AWARENESS OF MOBILE CONTENT DELIVERY BASED ON FINE LOCATION ESTIMATE

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Abstract: In this paper, to tackle with uncertainty in the real world, the light-weight ontology drive approach is proposed for the realization of context dependent services. We concentrate on position information and an operation history, as a user's context, and develop our location-aware content delivery system. The evaluation experiment of our location estimate engine is performed in Akihabara Software Showcase at Information Technology Research Institute. Furthermore, through the proofing experiment in Expo 2005 Aichi, our proposed architecture is confirmed to enables us to realize the real world application of context dependency. Finally, we compare our location-aware content delivery system and related researches, and discus the advantage of our system.

1 INTRODUCTION

Because of the rapid development of ubiquitous computing technology, various mobile services have been realized using personal devices, cellular phones and IC cards, including i-mode (NTT-DoCoMo, 2007), EZweb (KDDI, 2007), Suica (JR-EAST, 2007), and so on. These services emphasize information access during movement, but it is necessary to deal with rich context of users, such as operation histories as position information, to also provide context dependency. In fact, development of weak radio and positioning technologies make it difficult to realize context sensitive services in the real world. Therefore, research issues of uncertainty remain among various theories and applications.

To tackle these issues, two main approaches have been proposed. The first approach is realization of pull-type services based on passive IC-tag technologies. Although this approach can achieve extremely robust service to the uncertainty of device operation, the data utility in context dependency has been left in the operation of a user. Another approach is based on the logic of probability, including Bayesian networks. Although the introduction of various parameters enables detailed tuning, time and cost issues pertain in adjustment because of embedded logic.

From the standpoint of tackling uncertainty in the real world, we propose a lightweight-ontology drive approach to achieve context-dependent services. To distinguish the observed objects and the observing subject in a real-world application, ontologies of areas and services were developed. A mechanism of adjustment for the real-world application is developed in mapping between the proposed ontologies. Through the proofing experiment in Expo 2005 Aichi (EXPO, 2005), we have confirmed that our proposed architecture enables realization of the real-world application of context dependency.

2 DESIGNING CONTEXT AWARENESS

In this study, we specifically examine position information as a user's context because position information of a user shows the existence of relations with surrounding objects tells what kind of relationship the object has with the user. In this paper, the concept of ”Context Awareness” is realized through development of location-dependent content delivery. We apply an active RFID system as human location sensor because it is only location estimate system of a large

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number of visitors. However, there is no robust location estimate system in uncertain environment.

2.1 Bridging by Linearizing Simplification

By supposing that we can obtain an ideal environment in which radio wave conditions are extremely stable in the real world, the distance from an RFID tag to an RFID receiver is calculable based on the Received Signal Strength (RSS) of an RFID receiver. However, it is difficult in the real world to observe the RSS precisely for the reason that the received RSS by RFID receivers is extremely unstable even though an RFID tag remains in a single position. Moreover, the instability of radio wave conditions is also reported as a result of reflection and phasing phenomena.

To tackle real-world instability, we employ the number of detections of a tag ID as the key parameter for estimating its location, instead of the RSS. Regarding the robustness of computation, we propose a linearizing simplification to the relationship between the number of detections of a tag ID by an RFID receiver (antenna) and the distance from an RFID tag to an RFID receiver, we then regard this relationship as ”the closer an RFID tag is located to an RFID receiver, the higher the number of detections of a tag ID by an RFID receiver.” This linearizing simplification decreases the complexity of the location estimation algorithm and enables adjustment of the parameters in a practical period.

2.2 Lightweight Ontology

To realize a method of location estimation with the above approximation as a computational algorithm, we must clarify a distinction between a representation of how we recognize location and a parameter that indicates how a computation is adjusted to the real world. Furthermore, from the standpoint of practical use, it is necessary for the real-world application to complete both estimating location and adjusting parameters in a very short period.

From the viewpoint of ontologies, to maintain an adjustment of a practical application, we must distinguish an object that is observed and a subject that is observing: we must also devise a means to recognize the real world and a method to infer a location. Furthermore, both of the above ontological aspects of the location estimation must be compatible to realize a service that is effective in the real world. The above discussion underscores the necessity of simplifying a model of a location estimation and a strategy of a service that is provided. Therefore, to retain robustness for instability of the real-world environment, we employ a hierarchical representation of areas that are recognized and contents that are serviced. At the same time, strong restrictions and rigorous constraints are unnecessary from the computational aspect. Moreover, correspondence between areas and contents is considered as a parameter for adjustment. In this paper, the above architecture of a hierarchical structure including estimated locations and provided services with fewer constraints and parameters is designated as a lightweight ontology.

Figure 1: Aimulet GH+.

3 IMPLEMENTATION OF A CONTENT DELIVERY

3.1 System Architecture

In this section, we explain our location-aware content delivery system (Sashima, 2004) using Aimulet GH+, which is composed of Personal Digital Assistants (PDAs) and an active RFID, as shown in Fig. 1.

Aimulet GH+ was developed as a users' mobile device for our location-aware content delivery service in Global House, Expo 2005 Aichi. The system detects the location of a user with Aimulet GH+ every second. Based on the user's location, the system updates the content list containing some items of explanations about exhibits that are near the user's location. The user chooses one item from the content list and touches it on the display to play an explanation with sound, text, and graphics.

Our location-aware content delivery system comprises RFID antennas, RFID receivers, an RFID receiver server, a location estimate engine, and a con-

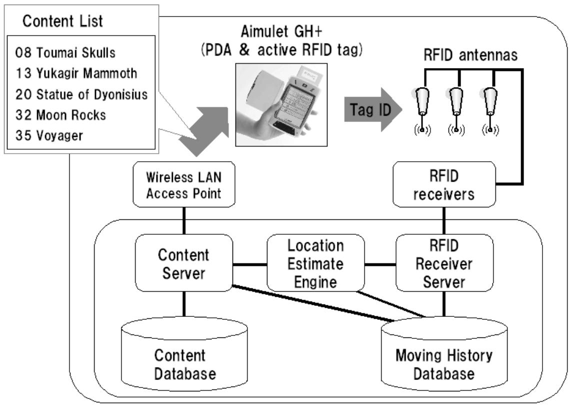

Figure 2: Data flow in the location-aware content delivery system.

tent server. The data flow of the location-aware content delivery service with Aimulet GH+ in Fig. 2 is as follows. An active RFID tag on Aimulet GH+ transmits its tag ID; then RFID receivers detect the tag ID through RFID antennas and send it to the RFID server. The RFID server stores RFID data (RFID receiver IDs detecting a tag ID and their respective time stamps). The content server sends the user's subarea to the content database, and requests a reply including the most optimal content list.

3.2 Location Estimate

The whole area is divided conceptually into subareas. The division method is conceptualization as layers; some kinds of layers are prepared. Subareas in the same layer have similar size. The sizes of subareas in the lowest layer are smallest of all layers. Higher-layer subareas are larger.

The location estimate engine selects one subarea in a layer where the user with Aimulet GH+ is considered, with the highest probability, to be located. First, the location estimate engine selects a subarea in the lowest layer containing subareas of the smallest size. Because the subareas in lower layers are small, selection of one subarea there is more difficult. Consequently, the location estimate engine chooses a higher layer containing larger subareas; it then tries to select one subarea within that layer. Based on the number of detections of tag IDs by RFID receivers, the selection is processed as follows.

First, a set of layers L is defined as

$$L = \{l_1, l_2, \ldots, l_i, \ldots, l_n\}. \tag{1}$$

Second, set of subareas S_i in layer l_i is defined as

$$S_i = \{s_{1,i}, s_{2,i}, \ldots, s_{j,i}, \ldots, s_{m_i,i}\}. \tag{2}$$

A set of RFID receivers R is defined as

$$R = \{r_1, r_2, \ldots, r_k, \ldots, r_l\}. \tag{3}$$

Each RFID receiver has a receiver point. Here, the receiver point $rp_{r_k}(id,T)$ for a tag ID id at time T is the number of detections of tag ID id by RFID receiver r_k for one second at time T.

To consider past RFID data of t seconds ago, a time weight of $w_{time}(t)$ is applied. With time weight $w_{time}(t)$, we define the total receiver point $trp_{r_k}(id,T)$ for a tag ID id at time T as

$$trp_{r_k}(id,T) = \sum_{t=0} w_{time}(t) rp_{r_k}(id, T-t). \tag{4}$$

Here, the time weight $w_{time}(t)$ is a monotonically decreasing function.

Each subarea has a subarea point. Here, subarea point $sp_{s_j}(id,T)$ of subarea $s_{j,i}$ in layer l_i for tag ID id at time T indicates how a user with Aimulet GH+ transmitting tag ID id is considered to exist in subarea $s_{j,i}$ based on receiver points around subarea $s_{j,i}$.

To calculate subarea point $sp_{s_{j,i}}(id,T)$, a contribution ratio is defined. The contribution ratio $c_{r_k}(s_{j,i})$ of receiver r_k to subarea $s_{j,i}$ in layer l_i indicates how the detection of RFID receiver r_k contributes to inferring that an RFID tag transmitting tag ID id exists in subarea $s_{j,i}$ when RFID receiver r_k detects the tag ID id. The value of the contribution ratio is determined based on this supposition: "The closer an RFID tag is located to an RFID receiver, the higher the number of detections of an RFID tag by an RFID receiver." Therefore, the closer an RFID receiver is to a subarea (or included into a subarea), the greater the contribution ratio of an RFID receiver to a subarea. Each contribution ratio is set as real number in the range of $[0, 1.0]$. With contribution ratio $c_{r_k}(s_{j,i})$, subarea point $sp_{s_{j,i}}(id,T)$ is defined as

$$sp_{s_{j,i}}(id,T) = \sum_{p=0}^{m_i} c_{r_p}(s_{j,i}) trp_{r_p}(id,T) \tag{5}$$

After calculation of all subarea points in a layer, the location estimate engine selects one subarea with the highest subarea point in all subareas in a layer. However, if little difference exists between the highest subarea point sp_1 and the second highest subarea point sp_2, the location estimate engine select no subarea in layer i; instead, it selects one subarea in the next-highest layer $i+1$. The condition by which the location estimate engine rises from layer i to layer $i+1$ is defined as

$$min\_ratio_{i,i+1} \leq sp_2/sp_1. \tag{6}$$

Here, $min\_ratio_{i,i+1}$ indicates the minimum ratio by which the location estimate engine rises from layer i to layer $i+1$. Otherwise, the location estimate engine considers that a user with Aimulet GH+ transmitting tag ID id exists in the subarea with the highest subarea point.

3.3 Content Delivery

The content database has a hierarchical structure of content lists and replies with a prearranged content list. For example, in a museum containing some exhibition rooms and passages with many exhibits, in the case that the content database receives a larger subarea in a higher layer, e.g. an exhibition room, the content database responds with a prearranged content list that includes (an explanation of) the concept of the room above and (explanations of) the main exhibits in the room below. In contrast, when the content server receives a smaller subarea in a lower layer, e.g., the place in front of a specific exhibit, the contents database replies with a prearranged contents list that has the exhibit above and other exhibits around it, along with the concept of the room below. However, not many such characteristic subareas exist in all subareas. Furthermore, it is difficult to assign a contents list a priori to each subarea because of the large number of subareas of all layers.

In light of the problems posed by these issues, lightweight ontology is introduced to connect the hierarchical structures of the subarea and the content list. The hierarchical structures of the provided content list and the estimated subarea are not equivalent. If the content lists are assigned to characteristic subareas and the hierarchical structure of subareas is defined, then, based on the subarea's hierarchical structure, the content database assigns the content list of the parent subarea to the subarea to which a content list was not assigned previously. For example, in the case of a subarea in a middle layer, e.g., the half of a room to which a content list was not assigned previously, the content database responds with the same content list as its parent subarea.

3.4 Evaluation Experiment

The evaluation experiment of our location estimate engine was performed in the Akihabara Software Showcase (SSC) at the Information Technology Research Institute (ITRI). In the Akihabara SSC, we constructed the same system as that in the Global House.

The Akihabara SSC area is 220 square meters (about 15 m × 15 m). In the Akihabara SSC, 30 RFID antennas and receivers are set on the ceiling. The whole area of the Akihabara SSC contains six parts shown in Fig. 3, which are named based on their facilities: lounge space, seminar room, closed meeting room, open meeting room, reception, and living room. Because the living room was under construction, it was impossible to enter it for our evaluation experiment. Five layers were prepared for the evaluation experiment, as shown in Fig. 4. Layer 4 had six subareas. Each subarea corresponded to a room of the Akihabara SSC in Fig. 3.

Figure 3: Ground plan of Akihabara SSC.

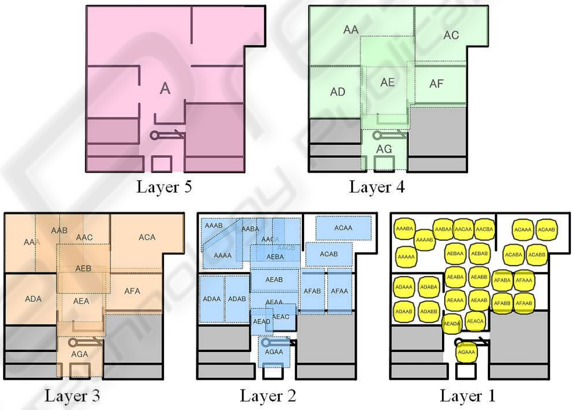

Figure 4: Division of subareas in each layer.

The tree structure of the subarea multi-layer system is portrayed in Fig. 5. In this structure, the parent of subarea *SEACA* is subarea *SEAC*, whose parent is subarea *SEA*. The tree structure of the content list is also shown in Fig. 5. Here, we show the case where the location estimate engine output subarea *SEAC* and *SEACA*, content database assigns a content list *R* based on the content list tree structure. The minimum ratios used in the evaluation experiment are shown in Table 1.

In our evaluation experiment in the SSC, a subject with Aimulet GH+ moved around the subareas in layer 5, and produced an actual subarea record (the subarea in layer 5 and time in which the subject existed actually). This one comparison is defined as a single trial. The correct answers were counted, and

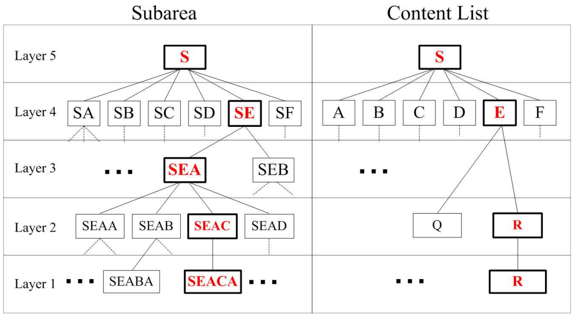

Figure 5: Tree structures of subareas and content lists in multi-layer system.

Table 1: Minimum ratio in each layer.

$min\_ratio_{5,4}$	0.001	$min\_ratio_{4,3}$	0.05
$min_{r}atio_{3,2}$	0.05	$min\_ratio_{2,1}$	0.1

the correct rate of each subarea was calculated.

As results of the evaluation experiment, the number of trials, the number of correct answers, and the correct rate are listed in Table 2. From Table 2, the correct rate of the location estimate engine in layer 4 was greater than 80% overall. In the Akihabara SSC, trial subjects were satisfied with the location-aware content delivery service using Aimulet GH+ because the provided content list was always suitable for the subject's location. Therefore, we confirmed that our location estimate engine had sufficient accuracy to provide appropriate content delivery services for users.

4 PROOFING EXPERIMENTS IN EXPO 2005 AICHI

Expo 2005 Aichi was held in Nagoya, Japan (EXPO, 2005) from March 25 through September 25, 2005 (Duration of 185 days). The pavilions were about 90; 22 million visitors attended. Global House had three parts: The Mammoth Laboratory , the Orange Hall, and the Blue Hall. The Orange Hall housed a model of the Yukagir Mammoth, Statue of Dionysus, Moon Rock, and a model of a Voyager spacecraft.

The Japan Association for the 2005 World Exposition required measures for a large number of visitors, i.e., information service of exhibits to visitors and for a reduced number of attendees. In the Orange Hall, a maximum of 350 visitors entered every 20 min from 9:30 AM to 8:00 PM. Based on such a requirement, we developed CONSORTS as both a content delivery system for visitors with users' mobile devices Aimulet GH+ and an exhibition management support service for managers.

Table 2: Accuracy of our location estimate engine in layer 4.

	trial	correct answers	correct rate
lounge space	449	406	0.904
seminar room	459	346	0.754
closed meeting room	270	239	0.885
open meeting room	280	227	0.811
reception	80	55	0.688
total	1538	1273	0.828

In Orange Hall, we provided the following exhibition management support for managers (Kurumatani, 2004), i) Detection of locations of individual visitors, ii) Research of listening rates of contents , and iii) Monitoring of hall congestion. As a result, we realized information services for visitors and obviated the need for about 50 attendants compared with a preliminary estimate.

5 DISCUSSION

In this section, we compare our context-aware content delivery and related studies, and discuss the advantages of our system.

Recently, elemental technology for location estimate has been developed and theoretical research for spatial information has been advanced. Regarding elemental technology, especially that which is related to location systems with Wi-Fi, the development of location systems with Wi-Fi has been astonishing in recent years; it has reached the practical use stage (EKAHAU, 2005; Aero*S*cout, 2005). Furthermore, location estimate with Bluetooth, which uses Bluetooth RSSI and access points with variable attenuators, has been developed (Bandara, 2004).

From the standpoint of comparison of ontologies, several spatial ontologies that describe physical space and spatial relations have been proposed, including both geometric (e.g., GPS, GIS) and symbolic representation (e.g., places that are identified by their names) of space: DAML-Space, OpenCyc, SUMO, Region Connection Calculus (RCC). A much-updated ontology was proposed recently by the Digital Enterprise Research Institute (DERI) on WSMO (WSMO, 2005). However, at present, each remains as a proposed description.

Moreover, services that use the ontology of location have been the subject of studies with similar aims to ours (Flury, 2004; Lemmens, 2004; Chen, 2004). However, the descriptions used in those studies represent simple recognition, e.g., ”the floor consists of a room and a passage.” These studies did not address performance in the real world. In another study, a trail provides the contents of context dependence with PDA in a real-time application in the real world (Sonntag, 2005). However, the clear separation of parameters and ontology is not established in that study. Our approach not only describes ”how we consider location information.” The characteristic of our research is mapping the structure of service: the structure of a contents list and the structure of physical area based on the properties of electromagnetic waves including a parameter are shown on a map as a representation of how we recognize location.

6 CONCLUSION

This paper presented a description of applications of the CONSORTS architecture to an integrated exhibition support system at the Orange Hall of the Global House at Expo 2005 Aichi. Furthermore, our location-aware content delivery system with Aimulet GH+ on CONSORTS was taken up as a characteristic implemented service in Orange Hall. Results of evaluation experiments of our location estimate engine in Akihabara Software Showcase at Information Technology Research Institute were obtained. They will be shown. Finally, outline of implemented services at the Global House, Expo 2005 Aichi and further evaluation and analysis of our system were provided.

REFERENCES

AeroScout (2005). AeroScout, http://www.aeroscout.co.jp/.

Bandara, U., H. M. I. M. M. H. A. T. (2004). Design and implementation of a bluetooth signal strength based location sensing system. In *IEEE Radio and Wireless Conference (RAWCON 2004)*, pages 319–322.

Chen, H., F. T. J. A. (2004). An ontology for context-aware pervasive computing environments. In *Journal of Knowledge Engineering Review*, volume 18, pages 197–207.

EKAHAU (2005). *EKAHAU - P*ositioning *E*ngine 4.0, http://www.ekahau.com/.

EXPO (2005). EXPO 2005 AICHI JAPAN, http://www.expo2005.or.jp.

Flury, T., P. G. R. F. (2004). Owl-based location ontology for context-aware services. In *Artificial Intelligence in Mobile Systems*.

JR-EAST (2007). Super Urban Intelligent Card (Suica) of East Japan Railway Company (JR-EAST), http://www.jreast.co.jp/e/index.html/.

KDDI (2007). EZweb, http://www.au.kddi.com/ english/ezweb/ index.html.

Kurumatani, K. (2004). Mass user support by social coordination among citizens in a real environment. In *Multi-Agent for Mass User Support, Post-Proceedings of MAMUS-03, Lecture Notes in Artificial Intelligence 3012*, volume 3012, pages 1–17. Springer Verlag.

Lemmens, R., d. V. M. (2004). Semantic description of location based web services using an extensible location ontology. In *GI-days*, pages 261–276.

NTT-DoCoMo (2007). i-mode, http://www. nttdocomo.co.jp/english/service/imode/index.html.

Sashima, A., I. N. K. K. (2004). Consorts: A multiagent architecture for service coordination in ubiquitous computing. In *Multi-Agent for Mass User Support, Post-Proceedings of MAMUS-03, Lecture Notes in Artificial Intelligence 3012*, volume 3012, pages 39–46.

Sonntag, D. (2005). Towards interaction ontologies for mobile devices accessing the semantic web. In *4th International Workshop on HCI in Mobile Guides*.

WSMO (2005). Web Service Modeling Ontology, http://www.wsmo.org/.