6-4 A Looking-for-Objects Service in Ubiquitous Home

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We have constructed test bed for proof experiment in real home environment ‘Ubiquitous home’ which have appliances and network and embedded many sensors in home environment. And we have done the proof experiments of home network interconnection and dynamic information services (distributed home network services) which cooperates sensors, home robots, the consumer electronics and appliances. In this paper, we describe a looking-for-objects service system which analyze the relationship of human and objects, and the change of the continuity of human behavior with the embedded sensors in ubiquitous home (especially floor pressure sensor) and find the place of lost properties. We examined the effectiveness of a looking-for -objects service by using sensor information in real family life scene at Ubiquitous home.

Keywords
Ubiquitous, Information service, Sensor, RFID

1 Introduction

Recent advances in ubiquitous technology have enabled the provision of user-adaptive information suited to a range of human needs, using various types of sensors to observe people’s daily surroundings, actions, and behaviors. Studies on context-aware information services have also become popular[1][2]. Further, by embedding wired and wireless sensors and various types of computers in the daily environment, we are now able to create a ubiquitous environment inside the home. These developments will allow people to enjoy a new range of information services provided by such computers, with richer lives as a result.

Under the auspices of the UKARI Project, our group has studied the creation of a collaborative and distributed functional network using the “UKARI Core”[3][4] and investigated new information services that will use the distributed environmental/behavior database constructed using information obtained by the network platform and sensors. These information services correspond to the context-aware services to be provided through home robots based on extensive integration of context-aware information on people and objects — acquired as raw data by sensors installed inside the house — and stored in the distributed environment/ behavior database. We have created a framework for these services that will enable each user to evaluate the information services provided, in order to provide feedback for the development of future services. A conceptual diagram of the context-aware services developed in the UKARI Project is presented in Fig. 1.

As part of this project, we undertook experiments in which a family unrelated to the project was asked to live inside the Ubiquitous Home for two weeks and to evaluate the various information services actually provided in the facility, as our team collected data from the sensors. The response to the various information services were generally positive, and the experiment allowed us to obtain data on

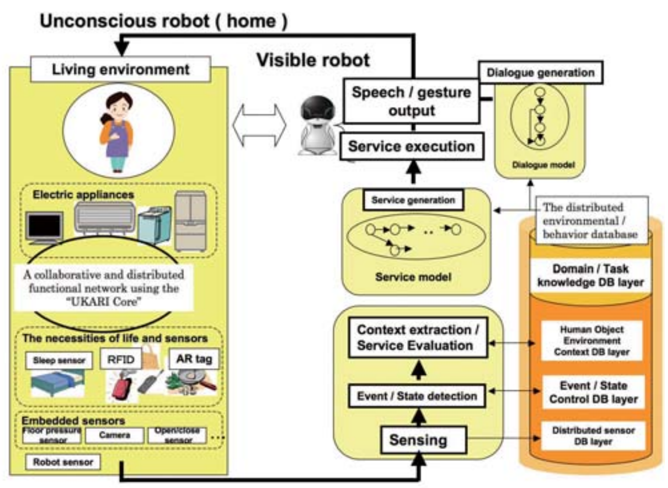

Fig. 1 *Conceptual diagram of context-aware services*

the round-the-clock behavior and actions of an average person inside the home and specific sensor data corresponding to these behaviors.

In the present paper, we will analyze human behavior in terms of mislaid objects inside the home, and introduce an "object search service" that will assist a person in his or her search for mislaid objects. We will then assess the results of a questionnaire completed by participants in the validation experiment as well as the archived records of their behavior, to determine the effectiveness of the object search service.

2 The object search service: Help in finding mislaid objects

We often find ourselves searching for misplaced objects, and in many cases, these situations arise when the relationship between humans and objects are changed, especially when the continuity of human behavior has been interrupted. Therefore, in our analysis, we have focused on the moment when an event changing the human-object relationship has occurred (referred to below referred to as an "interruption"). When the relationship between the person and the object does not return to the previous state after the interruption, the system will record the object as a potentially lost object in the database for the object search service. Then, if the subject of a misplaced object later comes up in conversation between the person and the robot (installed in the Ubiquitous Home), the objects stored on the database are presented as the potentially lost objects. This represents the essence of the object search service we have proposed[5]. The specific flow of the process involved is presented in Fig. 2. Details of each process will be described below.

First, an interruption event in the present service is defined as an event that affects any of the five human senses, triggering a change in behavior. Such an event may be detected by monitoring the changes picked up by the sensors surrounding the user using the distributed environment/behavior database. When a possible event of this type is detected, it will not be judged as an interruption when no change is observed in the person's behavior (Fig. 3). Candidates for an interruption event include a ringing doorbell, opening or shutting of a door to a room in which the user is located, switching on or off of the lights or the TV, changing the volume of the TV, a telephone call, and the movements of other people. For the present service in the Ubiquitous Home, the sensor information used to detect the interruption event will be listed for each room, and the object search service will monitor the information for any changes.

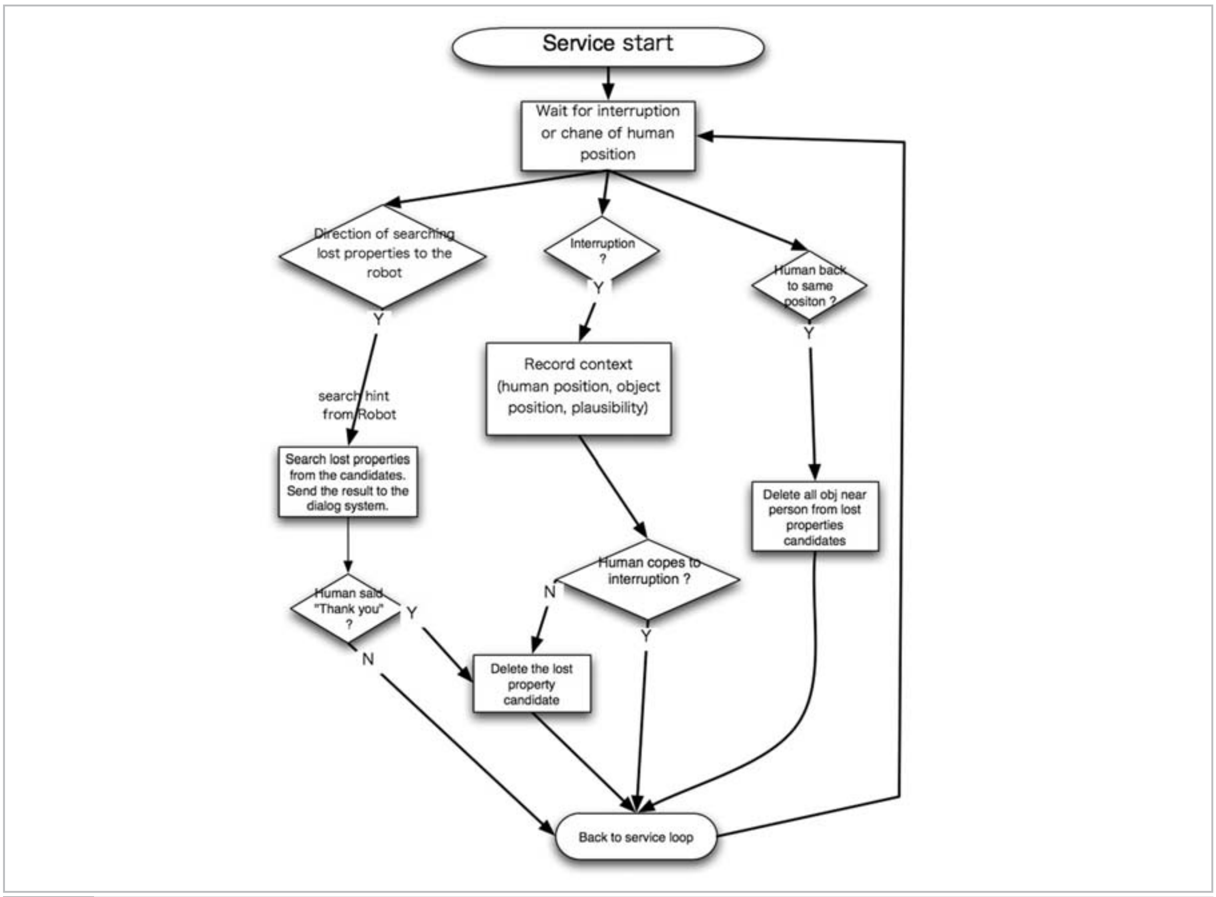

Fig.2 Flow of the object search service process

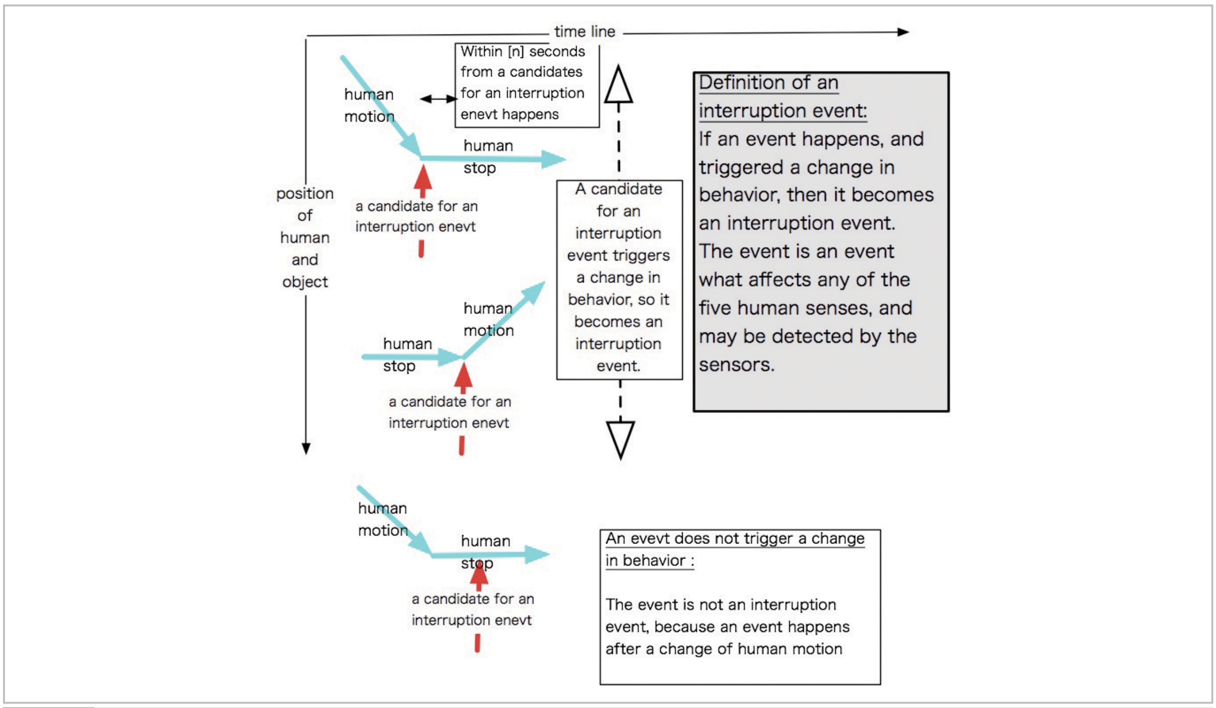

Fig.3 Definition of an interruption event

Next, the user/ object relationship immediately prior to the event must be recorded. To accomplish this, it is necessary to keep track of the relative positions of the user and the object that the user has come into contact with in the course of a given action. However, it is difficult to detect all such contact using the present sensor group and to record these events correctly on the distributed environment/behavior network. Therefore, we will settle for recording the relative positions of objects within a given distance from the user in question. In other words, user position information is obtained by tracking data from the floor pressure sensors, and the positions of all objects within a given distance from the user are recorded. Further, active RFID tags (Cubic ID Co., Ltd./ LAS300[6]) were attached to both the user and the objects, and the relative distances between them were measured by comparing the radio intensities of the tags.

Let us assume that the user responds to the interruption in some way, and then returns to his original position. At this point, the relationships between the user and the objects are rechecked; when there is a difference between the context recorded prior to the interruption and that after the interruption, the given object is added to the object-search candidate database. These steps are taken when a user is observed to have left a location for a while and then to have returned to nearly the same position, by tracking data from the floor-pressure sensors. Since the number of objects in the database often becomes enormous, candidates are evaluated for plausibility based on the relative movements of the user and the candidate object prior to the interruption (Fig. 4). In other words, objects that became stationary at the same time as the user and then started moving upon occurrence of the interruption are selected. This process gives priority to objects extensively involved in a series of user actions, or to objects held or transported by the user.

Conversely, the objects were ranked lower in terms of probability in the following cases.

(1) Objects that have been registered for a certain length of time without being mentioned in conversation

(2) Objects whose registered position has been shared by the user for a certain length of time (candidate object has most likely been rediscovered by the user)

Finally, the present service assists in the search when the subject of a misplaced object is brought up in the conversation between the user and the interface robot, as follows. In the

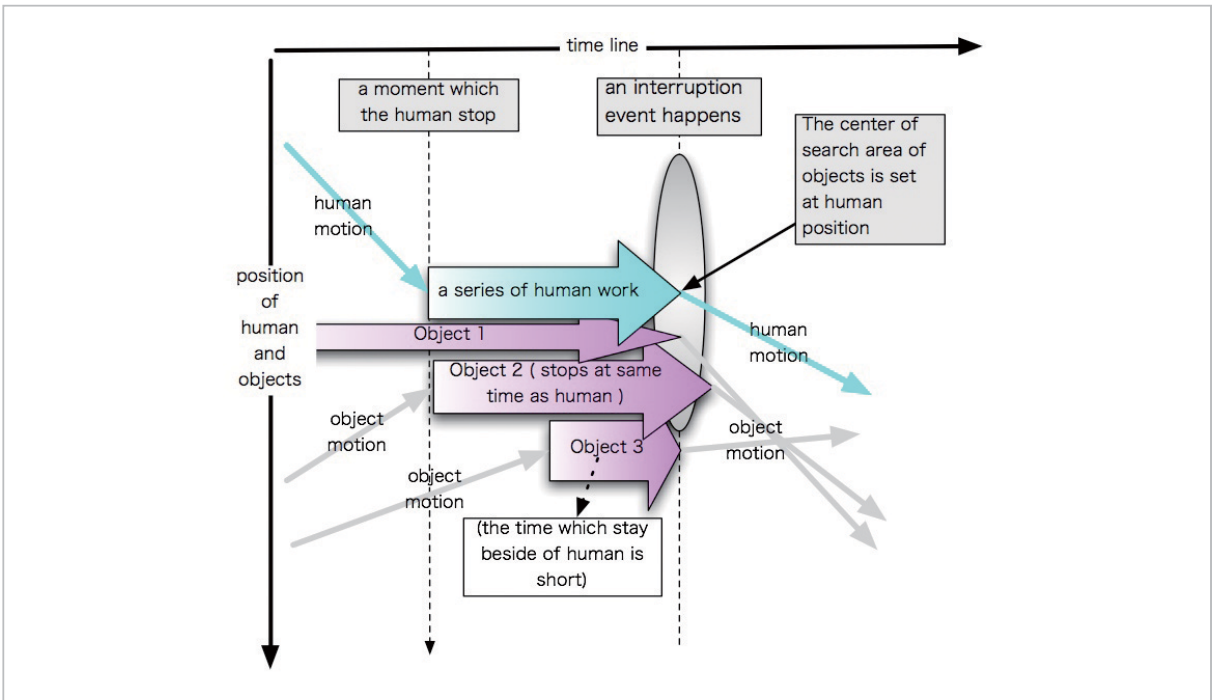

Fig.4 Plausibility of candidates in the object search service

Ubiquitous Home, a small physical robot, “Phyno”, works as an intermediary between the user and the various information services. When words recognized in Phyno’s system of conversation include one associated with a misplaced object, the object search service is executed. The user who is talking to the robot is identified based on information in the distributed environment/ behavior database, and the most likely candidate object is selected from the multiple candidates stored on the database. The system returns the name and position of the object to the robot, who will provide this information to the user in auditory form. If the user responds positively to the results of the service, the service judges that the object has been discovered by the user, the candidate is deleted from the list, and the service is completed.

3 Validation experiment of the object search service

Real-life validation experiments, in which common families were asked to spend about two weeks in the Ubiquitous Home, have been performed several times in order to validate and evaluate the various context-aware information services implemented. During these experiments, data from various sensors (such as cameras installed in the ceilings) were all collected and stored, with the consent of the participants. At the same time, each of the participants was asked to submit his or her answers to a questionnaire every day regarding changes in their impressions and evaluations of the various services, as well as their behaviors and events of the day associated with the service. Questions regarding the object search services involved the following.

- Did you forget to take something with you while you were dressing, or misplace anything, search for anything, or attempt to search for something during the day? (If so, what and when, and if possible, give the reason.)
- Where were the objects you attempted to find? Please indicate the general position using the number on the floor plan.

In order to verify the effectiveness of the object search service in the Ubiquitous Home, replies to the questionnaire submitted from the first real-life validation experiment (mid-April 2005) through the fourth such experiment (Oct. 2005) were examined to identify the cases in which such target situations for the service may have occurred. We performed a validation experiment to check whether the model of the object search service could be applied to these cases by combining the position of the user detected by various sensors with the observations of specific ceiling cameras. In other words, the place, time, and user identified in the questionnaire replies, and the position, time, and human behaviors relating to the candidate object were visually confirmed by the images from the ceiling camera, to determine whether the model could successfully explain the observed situation (Fig. 5). Cases occurring in rooms without ceiling cameras (outdoors, bedrooms, and lavatory) were excluded, as not suited to this analysis. Further, cases of forgetting to perform an act — such as closing the refrigerator

Fig.5 *Analysis of the service using ceiling-camera images acquired in the real-life validation experiment*

door — were excluded, since these omissions did not involve an object. Accordingly, we identified nine cases bases on the questionnaire replies for the four experiments (with four families) involving a search for a misplaced object. Of these, two cases involved a room unequipped with ceiling cameras in the path of the user or object, and so the analysis could not be completed. However, the model proved to be effective in all other places. Further, five cases involved multiple users of the object, and the proposed model could not accommodate the added complexity. In the remaining two cases, our model proved to be effective.

4 Conclusions

We recorded the relationship between users and objects during an interruption event, as digitized data obtained by sensors embedded in the environment. Based on a comparison of the data, we have proposed an object search service that will aid the user in his or her search for misplaced objects. We also performed basic analysis of the effectiveness of the present service in the Ubiquitous Home, based on sensor data records and replies to questionnaires obtained further to experiments in which participating families were asked to live in the Ubiquitous Home. Two out of the nine cases involving a search for an object involved a room that could not be properly included in the validation. In two cases, our model proved to be effective. The five remaining cases involved multiple users, and so our model was insufficient to handle these situations. In the future, we hope to modify and expand our present model to accommodate cases in which multiple users may be involved, to arrive at a service well suited to practical implementation.

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References

1 Hirotada Ueda, Akihiro Kobayashi, Junji Satake, Masaki Chikama, Jun Sato, and Masatsugu Kidode, “Dialog Strategy for Interactive Robot Interface in Home Network”, Special Issues on Collaboration Services in Ubiquitous Society, IPSJ JOURNAL, Vol.47, No.1, pp.87-97, Jan. 2006. (in Japanese)

2 Cory D. Kidd, Robert J. Orr, Gregory D. Abowd, Christopher G. Atkeson, Irfan A. Essa, Blair MacIntyre, Elizabeth Mynatt, Thad E. Starner, and Wendy Newstetter, “The Aware Home: A Living Laboratory for Ubiquitous Computing Research”, Proceedings of the Second International Workshop on Cooperative Buildings (CoBuild’99) Position paper, Oct. 1999.

3 Tatsuya Yamazaki, Masaki Yamauchi, and Yosuke Tajika, “Collaborative System Construction with Networked Appliances and Networked Sensors”, The Second IEEE Workshop on Embedded Networked Sensors (EmNetS-Ⅱ), pp.153-155, May 30, 2005.

4 Yamazaki Tatsuya, Sawada Atsushi, Nishimura Toshikazu, Takaoka Masanori, Tajika Yosuke, and Minoh Michihiko, “6-2 Distributed and Cooperative Service Platforms for Home Network Services”, This Special Issue of NICT Journal.

5 Tetsuya Fujii, Hirotada Ueda, and Michihiko Minoh, “The Looking for something”, service in home ubiquitous environment”, FIT2004, M-053, Sep. 2004.

6 http://www.k-ubique.co.jp/active/trial.html

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