A Unified Application Service Model for ubiHome by Exploiting Intelligent Context-Awareness

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Abstract. We propose a unified ubiHome application service model which provides user-centered services by exploiting intelligent context-awareness. Recently, most of research related to smart home focused on the infrastructure rather than a user, and did not consider effective use of context. Such approaches are not appropriate for a user-centered interface, intelligent home control, flexible extension of application service, etc. In this paper, we design a unified ubiHome application service model by exploiting ubi-UCAM (unified context-aware application model). The proposed model provides services corresponding to a user's intention and also supports flexible interaction between a user and ubiHome environment. It provides personalized ubiHome environment to each user. The proposed model contributes flexible interaction between a user and ubiHome environment. And it provides personalized ubiHome environment to a user and simplifies extension of various application services. Therefore, the proposed model helps ubiquitous applications obtain users' context and provide adaptive applications flexibly.

1 Introduction

Recently, computing technology has steadily developed. Ubiquitous Computing, called the forth revolution, is being reflected in our lives [1]. The future will be an environment that promotes interaction of human and computer by sinking many kinds of computing resources in our living space. Especially, intelligent user-centered services will play an important role in the future home environment [2]. And it is necessary to further develop context-aware technology and find out how context information can be applied to the design of various sensors and applications, for intelligent user-centered services [3][4][5].

Significant research related to smart home has been progressed. This includes Adaptive House (Univ. of Colorado) [6][7], AwareHome (GATECH) [8][9], EasyLiving (Microsoft) [10], and House_n Project (MIT) [11]. However, most of the related research mainly focused on the infrastructure rather than a user, and did not consider effective use of context for providing services corresponding to a user's intention. The existing research lacks thorough examination, which is about convenient user-centered interface and intelligent control of the smart environment. Moreover, it is difficult to extend application services flexibly by central management of application services. Also, it is difficult to generalize in real life because of their high cost

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and low-quality service. Furthermore, previous proposed system did not define effective integration model for a user-centered smart home application service [12].

In this paper, we propose a unified ubiHome application service model by exploiting ubi-UCAM, which employs intelligent context-awareness to overcome the limitation of the existing smart home [13]. We build a new kind of smart home and design a model which provides personalized service for each user. Also, we evaluate usability of the proposed model. It enables privacy protection and provides a user-friendly environment at low construction cost.

The proposed model has the following advantages. First, it provides flexible interaction between a user and ubiHome environment, and provides services corresponding to a user's intention. This is achieved by the user-centered design and intelligent context-awareness. Second, it provides personalized ubiHome environment by effective use of context. It is presented in which context is created by various kinds of sensors in 5W1H form. Finally, it simplifies extension of various application services through the distributed architecture for sensors and application services. In other words, it guarantees independence of sensors and application services. And it provides a user-friendly environment at low construction cost by employing inexpensive sensors such as On/Off switch, IR sensor and USB memory. It enables privacy protection by using ubiKey.

This paper is organized as follows: In Section 2, we describe intelligent context-aware model. In Section 3, we explain a unified ubiHome application service. Especially, we focus on user interface and discuss examples of ubiHome application services in detail. And the implementation and experimental results are explained in Section 4. Finally, conclusion and future works are presented in Section 5.

2 Intelligent Context-Aware Model

Many sensors and context-based application services have been embedded in smart home environment. It is necessary for context-aware technology to provide assistance for the particular work that a user wishes to do. Therefore, we use ubi-UCAM which provides application service through awareness of a user's intention and efficient management of context. ubi-UCAM is a model which efficiently integrates context and manages to provide the smart home application service that the user wants. The context is created by various kind of sensors in 5W1H (Who, What, Where, When, How and Why) form.

Fig. 1 expresses the structure of ubi-UCAM. The ubi-UCAM can have reasoned "Why" context, and grasp a user's intention by integrating preliminary 5W1H set. Therefore, a user-centered interface can provide the application service that the user wants by exploiting ubi-UCAM.

The ubi-UCAM consists of ubiSensor and ubiService. The ubiSensor creates preliminary context that all ubiServices can use. Preliminary context is the context of 5W1H form generated by single sensor. The ubiService consists of Context Integrator, Context Manager, Service Provider and Interpreter. Context integrator determines integrated context set by integrating preliminary contexts passed from several ubiSensors. Context Manager compares integrated context with context condition to execute

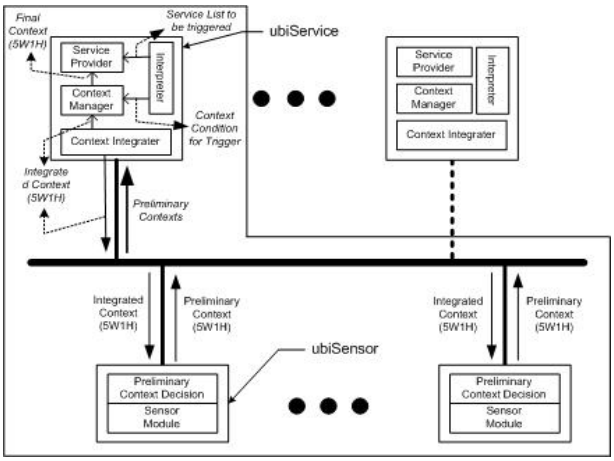


Fig. 1. ubi-UCAM structure, (a) ubiService (b) ubiSensor

specific service module. And then it generates final context and delivers final context to Service Provider. Service Provider triggers service module according to final context in service practice order. The user defines this order through Interpreter. Interpreter includes the defined context condition and service list that should be executed according to it. Context condition is registered in Context Manager. Information for service list, to be executed about each condition, is registered in Service Provider.

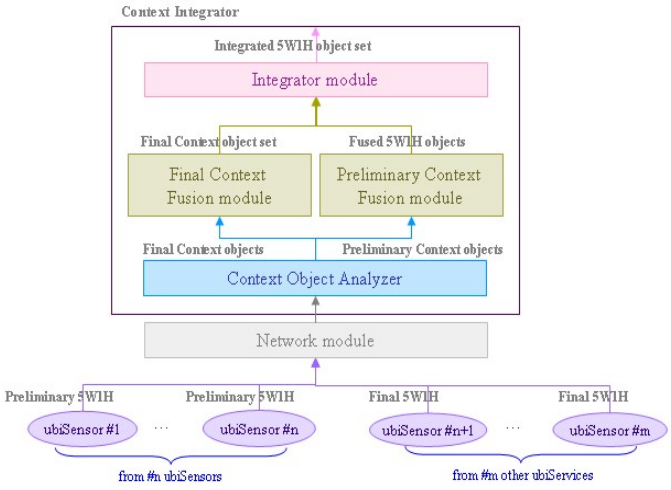


Fig. 2. Intelligent Context Integrator

Context integrator must make integrated context set, considering each preliminary context for intelligent context-awareness. And, Context integrator has intelligent structure that can infer a user's intention/emotion/sensibility and integrate various

application services that are provided according to the user's request. Intelligent context integrator consists of Context Object Analyzer, Preliminary Context fusion module, Final Context Fusion module, and integrator module. Fig. 2 demonstrates the interior structure of intelligent context integrator.

Context Object Analyzer aggregates preliminary context objects from n sensors and final context objects from m services. Preliminary Context fusion module receives preliminary 5W1H context objects from n sensors. By using decision fusion method, each context is fused with the "Who" information. Preliminary Context fusion module reconstructs each element of 5W1H by efficiently fusing imperfect preliminary 5W1H context objects. Next, it creates fused 5W1H objects by merging reconstructed 5W1H contexts. At this stage, this module can infer the "Why" information, that corresponds to a user's intention/emotion/sensibility, from the fused 5W1H context. Final Context fusion module makes final context object set by binding each final context object according to "Who" information. Finally, Integrator module integrates fused 5W1H objects to the "Why" context and create integrated 5W1H set.

3 A Unified ubiHome Application Service

The unified ubiHome application service incorporates cMP, cMail checker and Camera monitoring. Application services such as cMP, camera monitoring and cMail checker are integrated to each other through the context's flow. Organized interaction between application services is ensured by intelligent context-awareness of ubi-UCAM and Context Integrator. For example, while sitting on a couch watching movie, a user can observe outsider scene through camera monitoring. Also, he can check his E-mail, and send reply using a PDA. Fig. 3 displays the concept of a unified ubiHome application service.

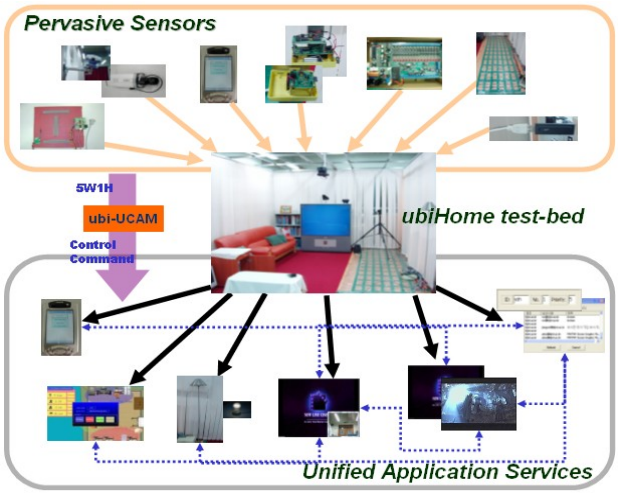


Fig. 3. Concept of a unified ubiHome application service

3.1 User Interface

User interface for a unified ubiHome application service model mediates among various kinds of application services distributed in smart home environment. A user can control several application services of smart home and can use personalized service based on his/her context. The user-centered interface plays an important role in creating context of a user's identification, location, action, emotion and intention etc. because the proposed model does not give inconvenience to the user to provide these services.

Fig. 4 shows user interface to efficiently control and use the proposed model. The user interface is embodied in order that a user is apt to use application service of movie appreciation, camera monitoring, and e-mail check. It is designed so that users can exploit indirect gesture commands through Space sensor [14] as well as direct control command through PDA.

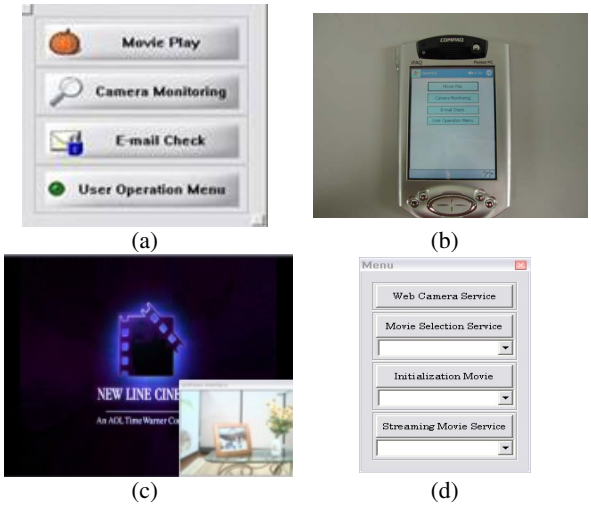


Fig. 4. User Interface (a) User menu on big screen (b) User menu on PDA (c) Camera Monitoring among movie screening (d) User Operation menu

3.2 ubiHome Application Service

cMP (Context based Movie Player). cMP is a smart home application service for movie appreciation that expresses personalized preference movie list, playing time and progress degree of each movie. cMP uses various kinds of sensors, such as ubiKey, ubiFloor, CouchSensor, and SpaceSensor. The personalized information is based on a user's profile in ubiKey [2]. Each function of cMP is controlled by context generated from each sensor observing a user's action. cMP supports various kinds of movie contents from cinema state database. Also, during a movie screening, cMP utilizes the camera monitoring service that can sense an outsider or confirm baby's state. Fig. 5 shows connection between cMP and each proposed sensor.

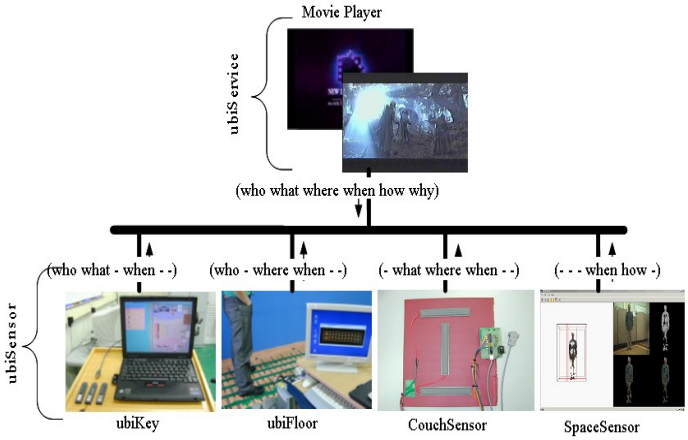


Fig. 5. Connection between cMP and each sensor

cMP starts with authentication of a user's ubiKey as he enters ubiHome environment. User profile is transmitted from ubiKey to ubiHome environment during the user authentication. When a user sits on a couch, he initiates application service cMP by selecting an appropriate menu. Fig. 6 instructs context flow between sensors and

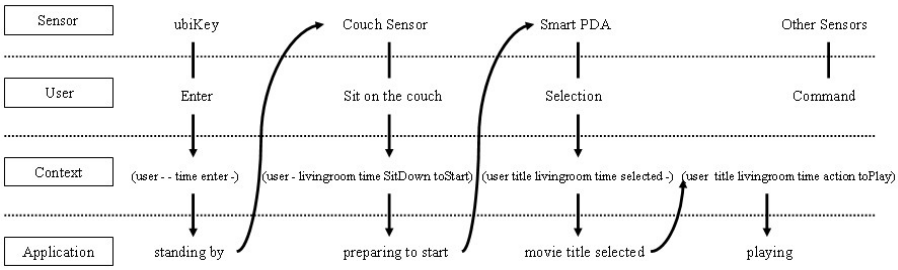


Fig. 6. Context flow of cMP

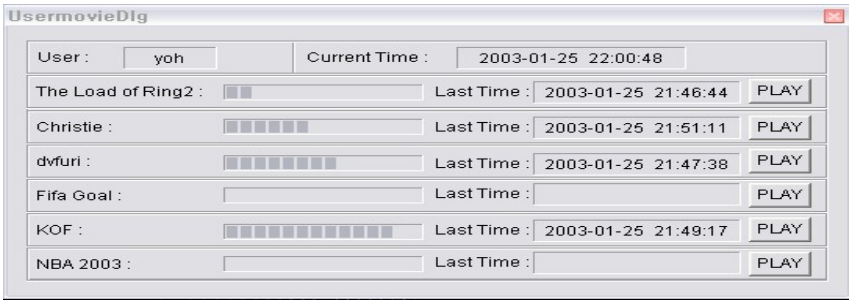


Fig. 7. Personalized movie information of cMP

the application service until a user enters smart home environment and receives the cMP service. cMP displays movie list that fits the user's taste. User's preference is determined by personalized profile information. Fig. 7 shows running times saved for each movie and the movie list reflecting the user's preference.

c**Mail checker (Context-based e-Mail checker).** cMail checker is a ubiHome application service that automatically supplies received mail message to a user according to his location. cMail checker uses various kinds of sensors, such as ubiKey, ubiFloor, CouchSensor, and PDA. cMail checker can confirm e-Mail from computing resources close to each user in ubiHome. Fig. 8 shows context transfer between cMail checker and sensors that create contexts. User information such as ID or password for e-Mail account is supplied in ubiKey. When a user leaves ubiHome, his personal information is stored in ubiKey. Fig. 9 shows arriving mail messages and mail status for a particular user. cMail checker can display received e-Mail on large screen or PC close to the user. User's location is tracked by ubiFloor [15].

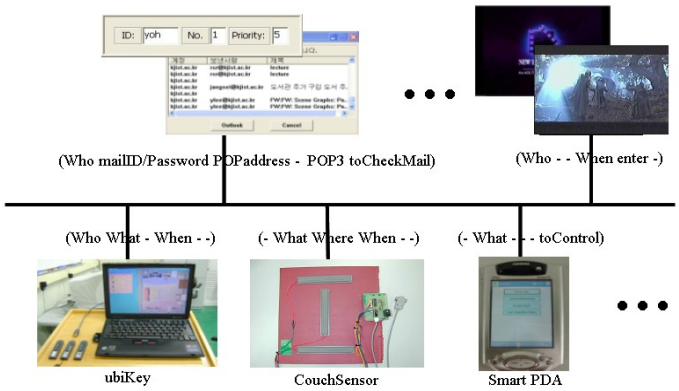
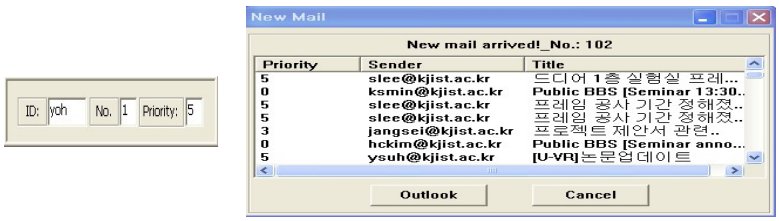


Fig. 8. Connection between cMail checker and each sensor



(a) (b)

Fig. 9. Personalized information of cMail checker (a) Current status of cMail (b) Received mails

4 Experiments

As shown in Fig. 10, various kinds of sensors such as ubiKey [2], Couch sensor, IR sensor, USB camera, web camera, PDA, space sensor [14], ubiFloor [15], RF tag etc.

are deployed in ubiHome, the smart home testbed at GIST U-VR Lab. Each sensor individually is linked to a PC and acts as a smart sensor with inherent processing, networking, and sensing abilities.

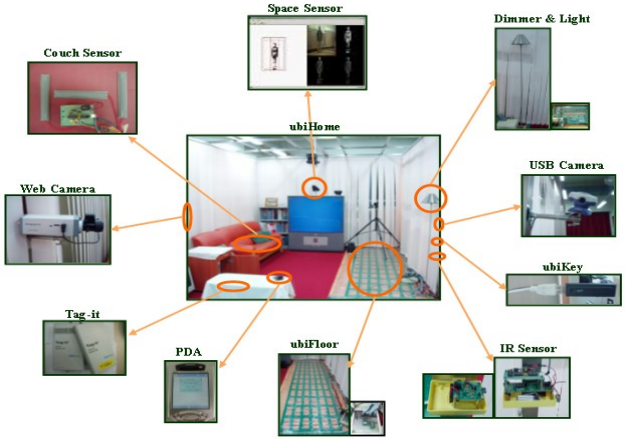


Fig. 10. ubiHome test-bed

All experiments are performed by using resources in ubiHome. We investigated the system's usability from 20 (10 adult, 10 child) ordinary people to evaluate the proposed model. The evaluation involved iterative experiment which provides application services in home environment. With an aim to achieve a user's satisfaction in the experiment, 4 general PCs (Pentium Ⅲ 800MHz, 512 GB SDRAMs), 1 Compaq PDA (iPAQ 5450), and proposed sensors were used.

About utilization of context, we quantitatively compared existing approaches with our application service model, such as cMP, camera monitoring service, and cMail checker. As shown in Table 1, we observed that the proposed model utilizes more rich context rather than existing methods. In Table 2, we analyze quantitatively provision of personalized service to users. We could know that users are satisfied with the proposed model because they can use service of their own.

Table 1. Quantitative analysis of context usage

Application service	The existing method	The proposed method
cMP	What (movie list)	Who(user name), What(movie title), When(entering time, play time), Where(living room), How(gesture), Why (ex. to play)
Camera Monitoring	Nothing	When (detection time)
cMail checker	Nothing	Who(user name), What(ID/PWD), Where(POP address), How(POP3), Why(ex. to check)

Table 2. Quantitative analysis of personalized service

Person (Age, sex)	ID/ PWD	Preferred service	Preferred light intensity	No. of Preferred movie (Total: 8)	Degree of satisfaction
User A (28, man)	YOh/ ****	cMP	20 %	4	85 %
User B (26, woman)	SjOh/ ****	cMail checker	100 %	1	75 %
User C (30, man)	SJang/ ****	cMP	40 %	3	80 %

We asked all 20 users to use ubiHome application services, such as cMP, camera monitoring service, and cMail checker. Then we estimate usability by averaging data formed from 20 users' average in Table 3. Average learning time means how long the user who does not use the proposed application service takes the time to perform the application service. As a result, we observed that each user achieved the task in average 17 seconds. Usage efficiency time represents when users who use more than one time reuse the application service. We also observed that the proposed model is efficient as a result of the usage efficiency time. In addition, we knew that users remember enough application service through system memory efficiency. Also, we estimated users' average rehabilitation rate about how frequently users have a mistake and return this when users use application service 1 time, with the following equation (1).

$$\text{Average rehabilitation rate}(\%) = \left(\frac{\text{Average No. of rehabilitation}}{\text{Average No. of mistake}}\right) \times 100 \quad (1)$$

According to the experiment results, we can know the proposed model gives enough satisfaction to users through the practical use of context and user-centered personalized services unlike the existing smart home application. As shown in Table 3, we can know users can easily return the mistake in use for the proposed model. In other words, the proposed model is user-friendly in ubiHome environment. Table 4 expresses necessity of the proposed model by making up a question concerning users' satisfaction. The proposed model provides correct services in a user's preference and intention. Therefore, users could use the proposed model conveniently even if they do not care specially about any devices of smart home.

Table 3. Usability test of the proposed model

Average learning time	Average usage efficiency time	System memory efficiency	Average rehabilitation rate
17 sec	8 sec	95 %	66 %

Table 4. Qualitative evaluation of satisfaction degree of the proposed model

Personalized information protection	Personalized service expression	Home environment control	User Interface	Reaction of user's motion	Connectivity of application services
70 %	85 %	80 %	65 %	95 %	90 %

5 Conclusion

In this paper, we proposed a unified ubiHome application service model which provides user-centered services by exploiting intelligent context-awareness. We presented the proposed model in which context is created by various kinds of sensors in 5W1H form. Our proposed model helps ubiquitous applications obtain users' context and provide adaptive applications flexibly. In future works, we plan to develop free communication of context through networking between application services and between sensors. In addition, we will consider group context creation method and practical use. This will smooth the interaction between smart environments and multi-users. Also, we need to develop intelligent agent which can deduce person's will. With this continuous development, we will establish a firm infrastructure for smart home environment.

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