The ubiTV application for a Family in ubiHome*

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Abstract. We present the ubiTV application which can help to implement a harmonious family in ubiHome, smart home environment. The ubiTV is a context-aware TV application for multi-user in ubiHome. Recently, several research activities on services in smart home have been reported, and the concern with user's environment has been growing. In this paper, we propose the ubiTV which recommends services (or contents) according to the residents' attention by resolving conflicts among multiple residents in smart home. The proposed ubiTV recognizes each resident's location and orientation in order to grasp residents' attention simultaneously. It infers their intention by integrating multiple inputs from a set of sensors. Also, it recommends the proper service or content to the specific resident by resolving conflicts. Therefore, it will be helpful for family-oriented home by recognizing attention, inferring intention, and resolving conflicts.

1 Introduction

Ubiquitous Computing enables to shift paradigm from technology-oriented to user-centered. Especially, the smart home is one example where applied technologies for flexible communication among members of the family are utilized. Residents in smart home can be provided with user-centric services by ubiComp-enabling technologies which can help to make a harmonious family. To strengthen family ties in smart home, we should consider sensing technology to recognize attention, technology to extract intention from various sensors. Also we should solve problems occurred while providing services to multiple residents.

Recently, several research activities on smart home services have been reported. EasyLiving (MS Research, since 1998) [1], AwareHome (GATECH, since 1999) [2], Adaptive House (Colorado Univ., since 1999) [3], House_n Project (MIT, since 2000) [4] are some of them. However, the existing research activities have some limitations. First, it is hard to recognize residents' attention simultaneously in smart home. Second, they do not show the proper method which integrates context inputs from various kinds of sensors to know residents' intention. Finally, they overlook resolving conflicts among multiple residents.

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Therefore, we present the ubiTV application which can help to implement a harmonious family in ubiHome. The ubiTV is a context-aware TV application for multi-user in ubiHome. In this paper, we discuss Location Awareness, Context Integration, and Conflict Resolution to implement it. The proposed ubiTV application recognizes each resident's location and orientation by using the location-aware sensor in order to grasp residents' attention simultaneously. It infers their intention by integrating multiple inputs from a set of sensors. Also, it recommends the proper services or contents to the specific resident by resolving conflicts among residents.

Furthermore, it has the following features. The ubiTV provides user-centric personalized services to residents by integrating and managing contexts obtained from heterogeneous sensors. It provides various services (TV, movie, MP3, internet, etc.) and gives information (weather, stocks, etc.) to residents. Additionally, it enhances communications among members of the family. It shows an application of technology to strengthen family ties by exploiting various home services.

This paper is organized as follows: In Section 2, we explain ubiHome test-bed with the ubiTV application. In Section 3, we describe context-aware technology in ubiTV. Especially, we discuss Location Awareness, Context Integration, and Conflict Resolution. The implementation and experimental results are explained in Section 4. Finally, conclusion and future works are presented in Section 5.

2 ubiHome Test-bed

The ubiHome is a test-bed for applying ubiComp-enabling technologies to home environments [5]. Various kinds of pervasive sensors and services have been embedded in ubiHome. Those embedded sensors and services form the foundation of the integrated smart home for multiple residents.

Context in ubiHome is defined by adding time context (context history) in addition to Schilit's definition. The context is represented in the form of 5W1H (Who, What, Where, When, How, and Why) by simplifying it [5][6]. Context modeling in ubiHome is based on ubi-UCAM 2.0 which is a unified context-aware application model [7]. It is used to recognize a resident's state, behavior and surroundings.

Pervasive sensors in ubiHome detect nearby residents and environments for the resident. As shown in figure 1, various kinds of sensors such as ubiKey, Couch sensor, IR sensor, USB camera, web camera, PDA, Space sensor, ubiFloor, ubiTrack, RF tag, etc. are deployed in ubiHome [5][8]. Each sensor individually acts as a smart sensor with sensing, inherent processing, and networking abilities.

Services in ubiHome are provided as user-centric services to multiple residents. The c-MP (context-based Media Player), c-Mail checker (context-based eMail cheker), TMCS (Tangible Media Control System), cPost-it (Context-based Post-it) are some of them [5][8]. Especially, ubiTV provides user-centric media services to residents based on ubi-UCAM 2.0.

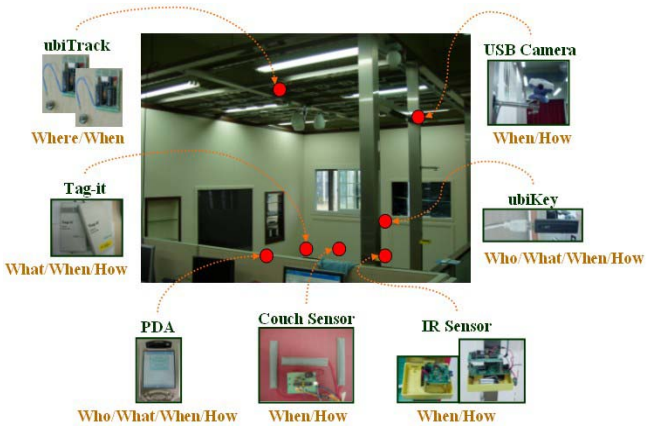


Fig. 1. ubiHome test-bed with various sensors

2.1 ubiTV application

The proposed ubiTV is designed to make a harmonious family by exploiting various smart home services. To strengthen family ties, it technically supports to get residents' experiences through the relationship among members of the family which consist of a married couple in the thirties and a young son. Thus, ubiTV recommends the proper services or contents to residents. Additionally, it shows a guideline that expresses expected experiences of residents in smart home. Through this guideline, developer can analyze the experiences of residents in smart home in advance.

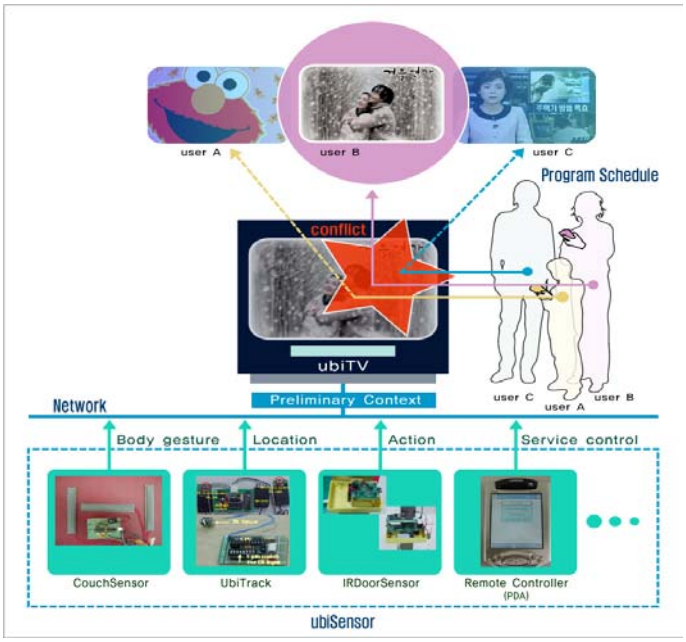


Fig. 2. The implemented ubiTV

The ubiTV has an architecture that recommends the proper menu (services or contents) to resolve conflicts. It also provides personalized services to multiple residents by exploiting ubi-UCAM 2.0. Figure 2 describes the implemented ubiTV. In figure 2, ubiTV understands that User A, B, and C want to watch TV at the same time from contexts obtained from ubiSensors, and then it recommends the proper contents to the selected User B by resolving conflicts. That means right of choice is given to User B. But in real life, people can also take parts in decision by talking together. In order to provide user-centric services, ubiTV utilized 5W1H contexts in table 1.

Table 1. 5W1H Contexts in ubiTV application

5W1H Context	Description
Who	a father (age 37), a mother (age 34), a son (age 7)
What	services or contents
Where	Somewhere in a living room (ubiHome)
When	time (in the morning/afternoon/evening, at night), history
How	a resident's gesture, movement, activities, behavior, patterns, etc.
Why	a resident's attention or intention

Additionally, ubiTV controls display devices by reasoning a resident's attention based on his location and orientation. Figure 3 represents residents paying attention to MRWindow which is a tiled display with 6-division monitors. At this point, ubiTV interprets residents' attention by using "Where" context (including location and orientation information) calculated in ubiTrack.

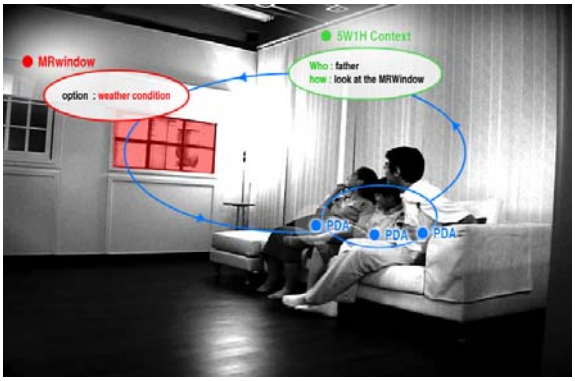


Fig. 3. Residents' attention on MRWindow

3 Context-aware Technology in ubiTV

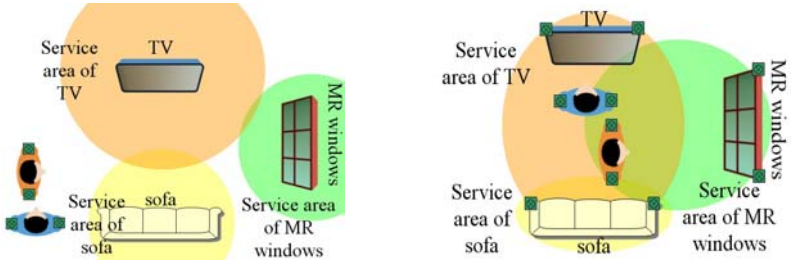
Context-aware technology in ubiTV is Location Awareness, Context Integration, and Conflict Resolution.

3.1 Location Awareness for Attention-aware

The ubiTV recognizes the residents' attention by exploiting location and orientation information of residents and objects. The ubiTrack is the infrared-based location tracking system which tracks the location and orientation of residents and objects indoors [9].

Classic location tracking systems provide service areas as figure 4(a), however they cannot recognize orientation of residents and devices [9]. In this case, the general application provides simple services according to only location. Namely, when a resident approaches TV from side or back, the resident still receives the TV service regardless of the resident's attention. However, the proposed ubiTV provides the service based on the resident's attention by removing the unnecessary areas, as shown in figure 4(b).

In detail, it provides specific services with consideration of a resident's attention by comparing orientation of a resident and a device. In other words, the resident is provided the service that he faces on. As shown in figure (b), the first resident is provided services in a TV because he watches the TV. The second resident who watches MRWindow is provided services not in the TV but in MRWindow, even though he is technically in the TV service area with MRWindow service rather than a TV service. Because ubiTV recognizes that he faces on MRWindow by his location and orientation from ubiTrack.



(a) Using classic system (b) Using proposed method

Fig. 4. Comparison between classical & proposed method

3.2 Context Integration for Context Inference

Context integration is a kind of decision making process which decides a meaningful integrated context. Context Integrator collects preliminary contexts at periodically from various kinds of ubiSensor which is placed in same active area with ubiService [7]. Then, it classifies the contexts as each element of 5W1H. It creates integrated context by applying the proper fusion method that reflects characteristics of each element. Figure 5 shows the architecture of Context Integrator. In figure 5, Preliminary Context Fusion module consists of each fusion of 4W1H (Who, What, Where, When, and How) context. Context Inference Engine reasons out "Why" context by using integrated 4W1H context.

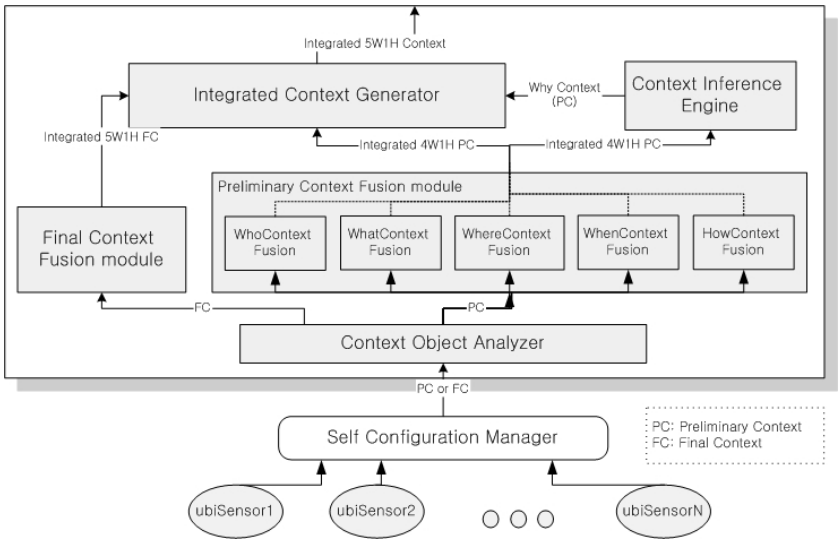


Fig. 5. The architecture of Context Integrator

Context Inference is used to reason out Why context (Attention or Intention) fusion. Context inference is based on context transition [10]. Context transition can get a new reasoned context by observing a change of the other contexts. For instance, there are location-change, proximity-change and function-time change. A change of "What"/"Where"/"When" context can infer a resident's attention. It shows that the device which adjoins the resident changes continuously. This means that available devices for the resident in a present place and present time changes.

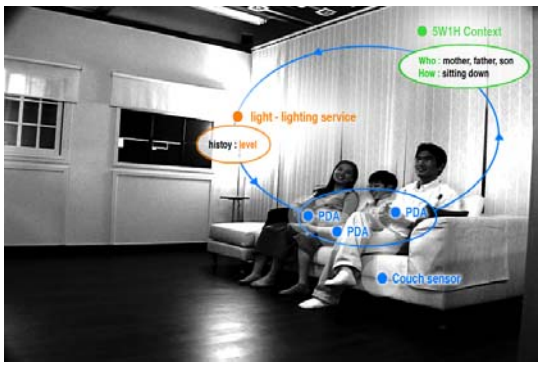


Fig. 6. Three residents' postures on a couch. Three residents sit in three seats

Context Integrator infers residents' behavior or gesture. At this point, previous contexts are important clues. Thus, context history is used to evaluate residents' behavior. Context Integrator can get coordinates on both shoulders of a resident through ubiTrack. We assumed that left shoulder has the coordinate (x1, y1) and right shoulder has the coordinate (x2, y2). By using those coordinates, a resident's orientation

can be calculated. Moreover, both coordinates and the orientation can be used to infer a resident's posture on a couch. If (x1, y1) and (x2, y2) are included in a sensor region, Context Integrator infers that the resident sits in a seat in the obtained direction. If (x1, y1) and (x2, y2) are included in different regions, Context Integrator infers that the resident occupies two or more seats in the direction. Thus, this inference can be used to extract residents' attention. Additionally, Context Integrator supports to extract residents' postures on a couch, as shown in figure 6. In figure 6, three residents sit in three seats. As a result of inference, it shows that the light service is automatically triggered to the proper level.

3.3 Conflict Resolution (Service or Contents Recommendation)

Context Manager is embedded in each service and provides Final Context to the registered service after resolving service conflicts [7]. Context Manager consists of Context Preprocessor, Conflict Manager, Service Profile Manager and Final Context Deliverer. Figure 7 shows the overall architecture of Context Manager.

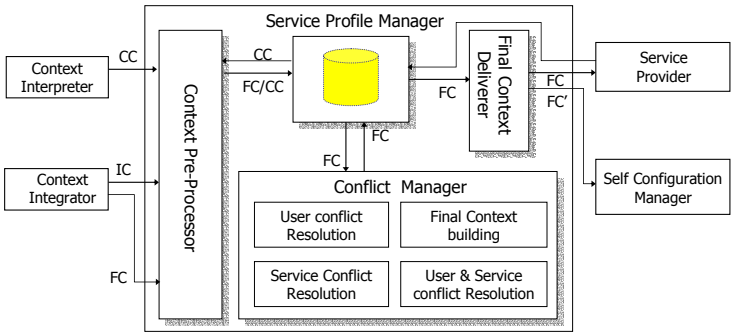


Fig. 7. The architecture of Context Manager

As can be seen in figure 7, Context Preprocessor receives integrated context and final context from Context Integrator. It also receives conditional contexts from Interpreter and Service Provider. Then, it stores the resulting contexts to Service Profile Manager. Service Profile Manager keeps track of the contexts and maintains conflict history of residents and services to resolve conflicts among residents and services. Conflict Manager resolves service conflicts among residents and services [11]. In order to resolve service conflicts, it recommends related information to residents. Recommendation is divided into Service Recommendation and Contents Recommendation. When conflict between residents is occurred Service Recommendation selects the service with highest priority based on residents' preferences among various home services. TV, gallery, game, taxes service are its examples. Lastly, Final Context Deliverer delivers a new FC to Service Provider and Self Configuration Manager. Contents Recommendation selects the content when residents want to use different contents in one service. For instance, when conflict is occurred between two residents in a TV service, ubiTV recommends the contents, such as news, animation and drama to them.

4 Implementation & Experimental Results

The ubiTV is implemented by using a physical TV device, a PC and several sensors, such as ubiTrack, Couch Sensor, IR DoorSensor, PDA, etc. in ubiHome. To evaluate the proposed components, we had several experiments.

First, we ran an experiment in order to find out the accuracy of orientation measured by ubiTrack. We attached two IR receiver modules on the shoulders of the resident, and measured his orientation by varying angles by 30° in the same position. To increase the reliability, we collect 100 IDs per each orientation. Figure 8 and 9 show the results of this experiment. Figure 8 shows the measured the resident's location. The practical location of the resident is (140, 130). Figure 9 shows a resident's orientation in each 30° degree sections and shows that all errors exist within 30°. In this experiment we can see that ubiTrack recognizes eight directions. It is enough to apply this technique to ubiHome to find the attention of multiple residents by using several ubiTracks.

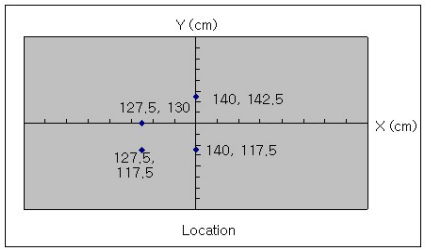


Fig. 8. Location of a resident

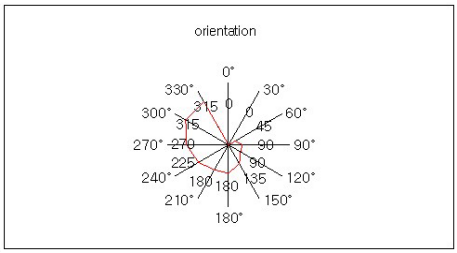


Fig. 9. Orientation errors of a resident

Second, we measured performance on reasoning out residents' intention by integrating multiple context inputs obtained from various sensors in ubiHome. We experimented how Context Integrator performed by inspecting user-centric integration and inference from a set of sensors. Table 2 shows the performance of Context Integrator. *Integration Interval* means the time period that Context Integrator decides each integrated context. In this experiment, Context Integrator integrates 10 context inputs at once in a given *Integration Interval*. *CPU occupying ratio* represents the usage of CPU when Context Integrator integrates contexts. *User-centric Integration (G/T)* is a measurement of how "Who" context fusion affects the integration. It is a ratio between the number of the generated integrated context (G) with a resident's identity and total number of input (T) in a given interval. Its result expressing the resident's identity is important because "Who" context fusion classifies the context input by the resident's identity.

Table 2. The performance of Context Integrator

Integration Interval	CPU occupying ratio	User-centric Integration (*G/T*)
0.1 sec	48 %	4/20
0.5 sec	32 %	1/20
3 sec	45 %	1/20

PC Env.: CPU PⅢ 800M, RAM 512M

G: the number of the generated IC with user's identity, *T*: total number of input

Accordingly, we could verify that Context Integrator is able to perform user-centric view by integrating multiple context inputs from multiple sensors. Additionally, we can see that Context Integrator has good performance when *Integration Interval* is 0.5 second, in order to infer a resident's intention based on his behavior.

At last, we experimented on conflict among residents in following setting, in order to measure the usefulness of the resolution method of Conflict Manager. We chose a TV service, because residents spend most of their time on watching TV in their home. While using the TV service, members of the family run into conflicts due to their different preferences. In our experiment, the TV service recommends preferred genres of conflicting residents in those situations. The service then gathers feedback from residents in pre-determined duration of time and counts the number of hits on the recommendation. We did this experiment from 18:00 to 24:00 in two weeks and obtained 185 feedback samples from three residents. Finally, we have built a hit matrix to see how well it worked. Table 3 shows hit ratio on the recommended genres of each resident.

Table 3. Hit ratio on recommended contents (genres in a TV) (unit :%)

Residents	Hits	News	Drama	Education	Animation.	Etc
Father	38	34	10	10	5	41
Mother	41	17	27	43	4	9
Son	44	12	21	17	22	28

As shown in Table 3, three residents show different characteristics on the recommendation. Father expressed higher selection on News program than that of other programs, but showed relatively low hit ratio than other residents. In case of mother, most of the hits are related to Drama program. Son selected various programs compared with father and mother. He also shows relatively higher hit ratio than the other two. However, they were unlikely to choose their preferred program soon after content recommendation. This is because Conflict Manager enabled them to spend their time on talking about the current program with recommended programs. They then decided a suitable program to accommodate those residents. Especially, mother encourages her son to watch educational programs when they are in together.

In order to observe hit ratio on service recommendation, we monitored the Media services in ubiHome. Table 4 shows the hit ratio on recommendation of service conflicts among media services given to different residents.

Table 4. Hit ratio on recommended services (unit :%)

Residents	Hits	TV	Music	Movie	Internet
Father	21	38	34	9	19
Mother	43	40	31	17	12
Son	55	30	16	25	29

As shown in Table 4, three residents showed different characteristics on each service recommendation. Father shows relatively low hit ratio than the other two. It means that he usually consents on a current service of other residents. However, mother and son selected another service rather than enjoying a current service. In case of mother, the selections were made for her family. On the other hand, son's selec-

tions were made for him. Nevertheless, we found that even though they changed the current service, they didn't choose their preferred program soon after the recommendation. They first spent their time on talking about the current service and recommended services and then decided a suitable media service.

5 Conclusions

In this paper, we presented the ubiTV application which can help to implement a harmonious family in ubiHome. This paper prepares a chance that enriches their mentality by providing various services of ubiTV to multiple residents in smart home. It establishes a foundation for user-centric personalized services based on residents' attention or intention. Additionally, the proposed ubiTV shows an application of technology to strengthen family ties by exploiting various home services. In near future, we will experiment the situation for resolving conflicts among members of the family in various daily activities and will do the usability test to evaluate whether our recommendation method is proper to every involved resident.

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