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A New Paradigm for User Interaction in Ubiquitous Computing Environment

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Abstract— **In this paper, we propose a seamless user interaction framework in ubiquitous computing environment. With the proliferation of ubiquitous computing concept in IT, technologies of context-awareness become a key factor of human-computer interaction. In addition, the concept of human-computer interaction is expanded from computer itself to content or environment. Therefore, it is required that a new paradigm for human-computer interaction in ubiquitous computing environment. In the proposed framework, it is supported that personalized user assistant, responsive content, and harmonious service environment. In order to provide these elements in a unified way, the proposed framework models each element as sensor and service, and uses user-centric context as a common protocol between sensors and services. To show the effectiveness of the proposed framework, we experiment how a user is able to interact with a smart home environment and intelligent virtual contents.**

Index Terms— **user interaction, personalized user assistant, responsive content, harmonious services environment**

I. Introduction

In Human-Computer Interaction (HCI), there have been many research efforts to develop intelligent computers as well as intelligent user interfaces. Since context-aware computing is introduced, context has been considered as an important factor in HCI [1]. In human-to-human communication, we use explicit information from our 5 sensory perceptions as well as implicit information from our experiences or knowledge. Likewise, if we use contextual information in HCI, we are able to interact with computers more naturally. In ubiquitous computing environments, however, the user interactions should consider not only computers but also intelligent contents or environments.

Most research activities on user interactions in ubiquitous computing are related to the utilization of context. For example, Active Badge system which delivers calls according to the user's location, ParcTab which supports official tasks based on PDA. In recent activities on new types of user interactions, Oxygen, Aura, and GUIR have been trying to provide comfortable user interfaces. In particular, we classify the utilization of context into user, virtual content, and service environment. Context Information Service (CIS), Conference Assistant (CA), and MIThril are good examples of the utilization of context in user's perspectives. Although they exploit contexts like identity, location of a user, they hardly provide personalization in user interactions due to shortage of contextual information or context-aware mechanisms for personalization. Regarding virtual contents, there have been several projects, for example, Oz project, Creature Kernel, and Personal Service Assistants. However, these projects do not take into account contextual cues of a user, but only focus on active responses of virtual contents. In projects relevant to service environment, Adaptive Control of Home Environment (ACHE), Gaia, and Reconfigurable Context Sensitive Middleware (RCSM) are representative research projects. Even though they consider various aspects (resource consumption, energy consumption, service satisfaction, etc.), they only deal with a single user or services conflictions among multiple users. As we have seen in short, it is noticed that there exists a seam in user interactions due to the followings: context is inconsistently modeled in different context-aware applications, user interface is a dominant barrier between users and applications because of less considerations of user's context, virtual contents (applications, services) are away from real environments due to lack of perception and reflection of reality (user and environment), services/users conflictions for the multiple users interactions are a little taken into account. Therefore, it is required that a new paradigm for seamless user interaction in ubiquitous computing environment.

In this paper, we propose a framework, UCAM, for seamless human-content-environment interaction in ubiquitous computing environment where UCAM stands for Unified Context-aware Application Model. The meaning of "unified" in UCAM is a consistent design or model for context-aware applications regardless of users, contents, and environments. The proposed framework provides specifications of development for personalized user assistant, responsive content, and harmonious service environment. In this specification, all applications are modeled as a set of sensors and services. In addition, the communications among sensors and services can be done with user context. The user context, in particular, is able to describe any information with a consistent way that possibly occurs in user interactions. In order to support seamless interaction framework, moreover, we define the role of other computing paradigms as follows. Mobile/wearable computing can be used for personalized user

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assistant, virtual reality (VR)/augmented reality (AR) can be a good platform for responsive content, pervasive/ubiquitous computing can be an appropriate concept for harmonious service environment. The detailed explanations are followed in section II. The UCAM provides developers or researchers with a specification of new type of user interactions in ubiquitous computing environment.

This paper is organized as follows. In section II, we explain several terminologies in detail that we define in this paper. In section III, we show the details of the proposed framework from concept to architecture and its components. In section IV, we show experimental results of seamless user interaction in the given test-bed. Finally, we conclude and discuss future works in section V.

II. Definitions

From virtual reality to ubiquitous computing, a key factor in the new concepts of computing paradigms is a novel human-computer interaction. After context-aware computing is introduced, most researchers in HCI are focused on how to use contextual information to provide effective and natural user interactions. Although the previous research stresses that utilizing contextual information is important, the utilization of contextual information is not yet well defined in HCI. Therefore, we suggest the places which the contextual information should be applied (e.g., personalized user assistant, responsive content, and harmonious service environment), and we define each terminology in this section.

A. Seamless User Interaction

Any user interaction with content and/or environment reflects both virtual contents and real environments simultaneously through user context as a common protocol.

B. Personalized User Assistant

Personalized User Assistant (PUA) is a kind of user agent that can reflect user's context into user interface, learning user's profile (personal experience, preference, intension on a certain application), and controlling disclosure of user's context. In general, user's context is dynamically changed when he or she moves around. If the user wants to interact with applications or services in such situation, the user assistant should also recognize the changed user's context, and reconfigure the interface and update the user's context by reflecting current user's context. Contrary to the traditional HCI where users have to learn the user interface of applications, PUA learns the users by observing variations of user's context. Consequently, users can interact with any application as well as computing resource at any time and at any where. Thus, we can define PUA as a new paradigm for mobile and wearable computing in ubiquitous computing.

C. Responsive Content

Responsive Content is personalized reactions of the content that are corresponding to the user's direct manipulations and contexts (i.e., intention, attention, emotion, etc.). However, most related works are focused on intelligence of virtual contents which mimic human-beings' brain. In addition, they provide the same contents with a little consideration of user's contexts. Thus, the previous works are difficult to satisfy user's expectations to contents. To overcome these inconveniences, responsive contents should reflect user's explicit information as well as implicit information.

D. Harmonious Service Environment

Harmonious Service Environment is a smart environment that provides not only customized services with users based on their contexts but also harmonious services with users by mediating the multiple users' demands. The previous works take a little into account various conflicts in a smart environment since they mainly focus on a single user. For example, a service has to be faced with conflicts among multiple users when the users assess the same service simultaneously or when they access different services that share the same resources. In order to overcome these limitations, harmonious service environment based on users' contexts allows services to collaborate each other and enables them recommend and mediate the conflicts.

III. A Seamless Human-Content-Environment Interaction Framework

The proposed UCAM (Unified Context-aware Application Model) for seamless user interactions is a framework that provides not only acquisition, process and awareness of contextual information but also a unified way of representation with respect to user, content, and environment. Thus, the UCAM enables developers to build context-aware applications with less consideration of context manipulations. Fundamental concept of the UCAM is to provide developers with seamless interactions by applying human-to-human interactions into human-content-environment interactions. In general, a toolkit or framework provides developers with a sequence of procedures, and lets developers think only the logics of the application or service. Thus, the proposed framework helps developers who want to use context to implement context-aware applications by providing hardware interface, context transformation, context awareness, and interactions. In addition, the framework enables developers to reduce construction time and complexity of context-aware applications.

A. Architecture

The advantage of UCAM is a consistent and unified structure of context-aware application by applying the same structure into user (wear-UCAM) [2], content (vr-UCAM) [3], and environment (ubi-UCAM) [4]. Figure 1 shows the structure of UCAM and its instances.

As shown in Figure 1, the UCAM can support user-centric interactions in ubiquitous computing environment by providing the same structure to the developers. Thus, the UCAM can reduce unnecessary development costs or discussion time. On the other hand, the network interface can be implemented without strict guidelines because it should work in various

platforms and support various sensors. The context interface makes applications communicate with one another. The detail explains are follows in the next sections.

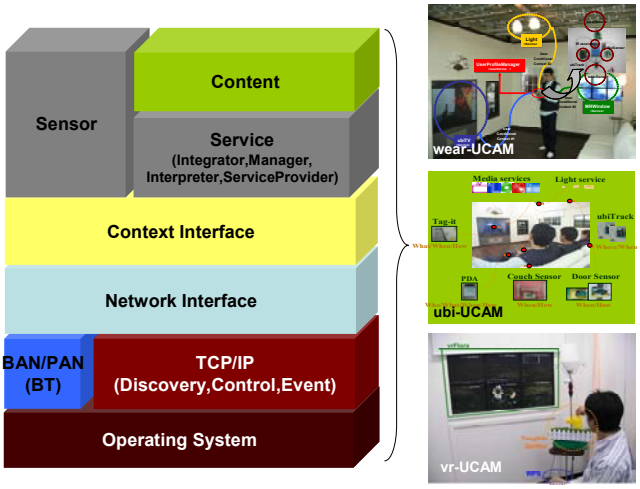

Fig. 1. Architecture of UCAM and its instances

B. Context

Although context is still in its ambiguity, many researchers have tried to define and classify context as detail as possible. For instance, Ghita (2004) classifies contextual information 2 categories based on application domain and its aspects. Schilit (1994) categorizes context with user context, computing context, and physical context. In addition, he proposes 4 fundamental context types as location, identity, time and activity. He also suggests that various contexts can be inferred from 4 fundamental contexts. Meanwhile, Gwizdka (2000) separates context into internal context and external context. Internal context represents status of user which includes tasks, personal events, communication and emotional states while external context represents environmental elements which include location, time and proximity of objects. Petreelli (2000) also divides context into physical element and social elements. Physical context includes location, device or available infrastructure, etc., whereas social context includes characteristics, preference, and interest of a user. In general, classification of context is not clear as well as is dependent on applications. With this ambiguity of context classification, we come to define user-centric context as follows.

"User-centric context is a set of description on user's states that influence an application's behaviors interesting to the user".

In this definition, a user can seamlessly interact with services and/or contents in ubiquitous computing environments by delivering user-centric context. To describe user-centric context, we exploit Kipling's method (5W1H) and we also define 5W1H (who, when, where, what, how and why) as contextual elements for user-centric context. Figure 2 and Table 1 is the conceptual separations of context and its description.

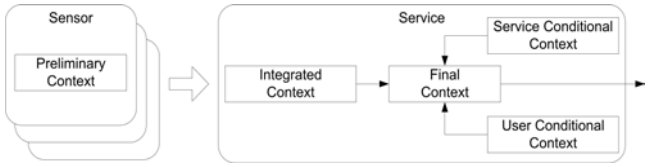

Fig. 2. Conceptual context representations in sensor and service

Table 1. Context categorization and its description

Context	Description
Preliminary Context: **PC**	Information that is generated from arbitrary sensors through primitive signal processing, and is structured as 5W1H
Integrated Context: **IC**	Information that is generated from *ContextIntegrator* which requires preliminary context from more than one sensor through integration algorithms
Final Context: **FC**	Information that is generated from *ContextManager* which creates the required execution commands for specific applications based on integrated context, user conditional context, and service conditional context
User Conditional Context: **UCC**	Information that is generated from Interpreter which acquires explicit user's preferences or relevant information to the user from the user
Service Conditional Context: **SCC**	Information that is generated from *ServiceProvider* which usually describes properties of a service such as parameters for service executions

C. Sensor

In the UCAM, the role of sensor is acquisition of user's internal and external states (i.e., location, body states) as well as environmental states, contextual transformation, and delivery of context to the service. Figure 3 shows the structure of sensor in the UCAM.

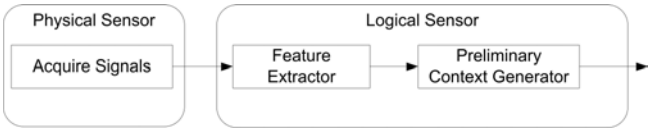

Fig. 3. Structure of Sensor in UCAM

As shown in Figure 3, the feature extractor analyzes the acquired signals from the physical sensor, and extracts useful features. With the features, the sensor can generate the preliminary context. Then, the generated context can be delivered to services.

D. Service

The role of service in the UCAM is a container that provides appropriate services to users. It can support conflict resolution between services, inference of user's intention, and execution of contents. Figure 4 illustrates the structure of service components and their functionalities in the UCAM.

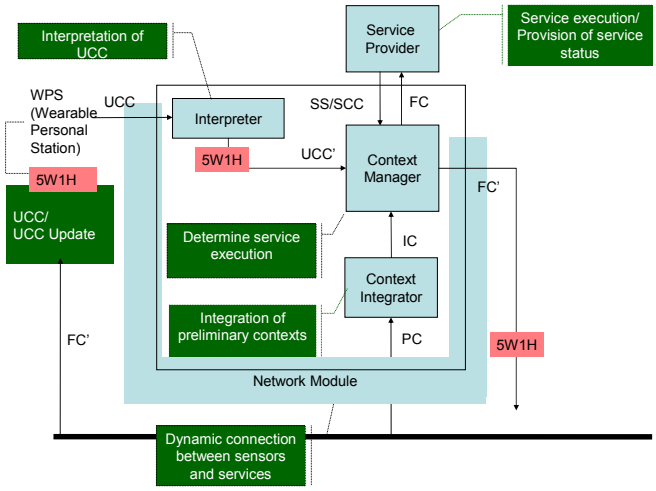

Fig. 4. Structure of Service in UCAM

As shown in Figure 4, service consists of several components; Context Integrator, Context Manager, Interpreter, and Service Provider. Table 2 shows the description of each component in the UCAM.

Table 2. Components of Service in UCAM

Component	Description	In	Out
Context Integrator	Through the integration of preliminary context from sensors, inferring user's intention or emotion	PC	IC
Context Manager	Generating final context to execute appropriate service by comparison and analysis of the integrated contexts and the user's conditional contexts	IC, UCC, SCC	FC
Interpreter	Interpreting user's explicit input to context which *ContextManager* can understand	User Input	UCC
Service Provider	Executing service based on the final context	Service Status	SCC

Thus, developers who use the UCAM do not have to consider the details of context and its awareness due to the UCAM provides the necessary procedures.

IV. Experimental Result

In this section, we show experimental results for seamless human-content-environment based on the UCAM. Figure 5 shows the interactions between the PUA and responsive content, and between the PUA and harmonious service environment. As shown in Figure 5(a), PDA shows different user interfaces because user A and B have different preferences on each service. That is, the user interface is reconfigured based on the user's preference which can be aware of contextual information from sensors. On the other hand, user A and B want different contents with the same device or application as shown in Figure 5(b). The application mediates the two users by showing appropriate contents list. Thus, the user A and B can have recommendations from the application.

(a) Personalized UI (b) Recommended Service

Fig. 5. Interaction in UCAM

V. Discussion and Future Work

In this paper, we proposed a seamless user framework in ubiquitous computing environment. In addition, we defined several terminologies with respect to personalized user assistant, responsive content and harmonious service environment. Through the experiment, user-centric context can play a key role of seamless user interactions. However, the user-centric context should be revised to communicate a user and a content or service. Moreover, the proposed framework only focuses on software architecture with primitive context-awareness. Thus, we need further investigations on modeling for contextual information as well as awareness of each component in order to support consistent user interactions. Furthermore, we should also consider other standard protocols or libraries for seamless interactions among instances of the UCAM.

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