Ubiquitous Virtual Reality and Its Key Dimension *

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Abstract

Computing technology is radically changing the manner in which we work and communicate with computers. Ubiquitous Virtual Reality (U-VR) has been researched in order to apply the concept of virtual reality and its technology into ubiquitous computing. In this paper, we present key dimension of Ubiquitous Virtual Reality (U-VR). The key dimenson are Reality-Virtuality, Static-Dynamic Context, and Personal-Social Activity continuum. Various paradiums including (U-VR) are classified into this 3D space. Future research direction for U-VR is also discussed at the end of this paper. We expect the key dimension will guide the future research direction for U-VR.

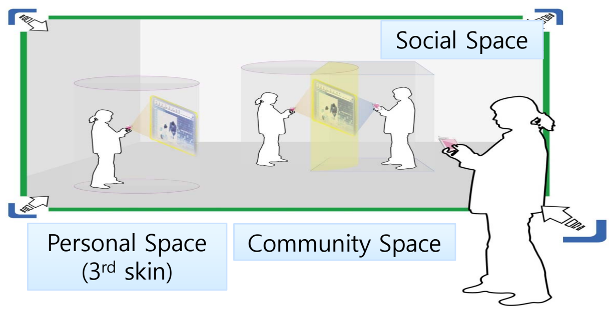

Figure 1. Spaces in the future computing environments

1 Introduction

With the advant of new computing technologies, ubiquitous virtual reality has appeared for seamless connection between real and virtual world. Ubiquitous virtual reality produce intelligent space that is converence of real and virtual worlds to increase human quality of life. By fusing real and virtual worlds with technologies, the advantage of virtual worlds moves to real world and the advantage of real world moves to virtual worlds. In this infrastructure, the manner in which we interact with computers in our living space will change. Community space is expected to change as intelligent space from smart space. Human's personal space will increase the freedom by wearing wearable computers. Thus, people will be provided with personalized services which also support social relationship.

In 1991, Mark Weiser discussed ubiquitous computing that computing resources that are embedded into our daily life [17]. In 1990s, wearable computing had been researched actively with mobile augmented reality at MIT and CMU [13, 5]. In 1997, Azuma published a survey on augmented reality (AR) [2]. Steve Mann described his wearComp (Wearable Computer) invention as a tool for "Mediated Reality" [9]. With the historical background, researchers think that how these computing paradigms will be changed in future. In 2005, Jang wrote that "U-VR is a new paradigm combining virtual reality with ubiquitous computing. This can provide user with various applications according to the context of users or environments". In this description, 'context' is a key factor to combine virtual reality and ubiquitous computing. However, it was conceptual without concrete characteristics.

In this paper, we present key dimension of Ubiquitous Virtual Reality (U-VR). The key dimenson are Reality, Context, and Activity. Various paradiums including (U-VR) are classified into this space. Future research direction for U-VR is also discussed at the end of this paper. We expect the key dimension will guide the future research direction for U-VR.

2 Background U-VR

Recently, Metaverse roadmap was presented, and Groups of MPEG-V (MPEG for Virtual World) and RoSE (Representation of Sensory Effects) for standarzation are working actively. The Metaverse roadmap deals with sce-

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narios about virtual world combined with real world: virtual world, mirror world, augmented reality, and lifelogging [14]. MPEG-V and RoSE are influenced by Metaverse roadmap. Accordingly, to combine virtual and real worlds with sensors and network is major issue the future computing paradigm.

U-VR has been researched in order to apply the concept of virtual reality and its technology into ubiquitous computing environments [7, 8]. The idea comes that the limitations of virtual reality could be improved through the new computing paradigm, on the other hands, the problems when we realize ubiquitous computing (ubiComp) could be solved by conventional virtual reality technology. Kim et al. discussed how VR and ubiComp help each other to overcome the limitations [7]. VR is still far from users in Real world and it has no killer applications in our daily lives. UbiComp is novel paradigm and many technical problems are raised currently such as user interfaces, context-awareness with artificial intelligence, collaborative networking, resource sharing, and others. Those problems has been researched and discussed in VR research field.

By supplementing the weakness of VR, we look for ways to evolve VR in ubiquitous computing infrastructure. The ideal of virtual reality (VR) is a technology which allows a user to interact with a computer-simulated environment (virtual environment) by stimulating all five senses. The ideal of ubiquitous computing was described by Mark Weiser as that of unobtrusive, “ disappearing” technology. As Weiser pointed out, ubiquitous computing and virtual reality have opposite characteristic, and yet have the same purpose [15]. Virtual reality extends human abilities in a virtual space which is constructed by computers, while ubiquitous computing extends human abilities in real space by developing networked infrastructure, smart objects, etc.

3 U-VR Key Dimension

Reality, context, and activity are important to understand U-VR. U-VR was defined as “A concept of creating ubiquitous VR environments which make VR pervasive into our daily lives and ubiquitous by allowing VR to meet a new infrastructure, i.e. ubiquitous computing” [7]. Question is how much real and virtual world have to be combined. In order to answer this question and to understand U-VR, we need to distinguish characteristics between real and virtual world. In human life, both context and activity are important, and many research activities have reported to understand these.

Reality-virtuality continuum was introduced by Milgram [10]. According to Milgram’s idea, real world is “any environment consisting solely of real objects, and includes whatever might be observed when viewing a real-world scene either directly in person”. Virtual world is a computer-generated world to enable a user to feel realism through interaction that stimulates five senses of a human. Between real and virtual worlds, there are augmented reality and augmented virtuality which are called mixed reality. His paper only discussed reality-virtuality continuum in the aspect of visual display. However, we could expand his idea not only visual display but also other human senses such as audio, haptic, smell, and taste.

Context is defined as ‘any information that can be used to characterize the situation of an entity, where an entity can be a person, place, or physical or computational object’ [1]. Context in real world is changing as time goes on. Context could have different representation according to time granularity. For example, if we observe static image, we can describe the content in the moment image taken. If we watch the next scene during few minutes, we can explain what happened. Thus as much as we observe situation, we can understand the context deeply. In this aspect, we call static context if it describes information such as user profile. On the other hand, if it describes wisdom obtained by intelligent analysis, it is called dynamic context. Figure 2 shows static-dynamic context continuum.

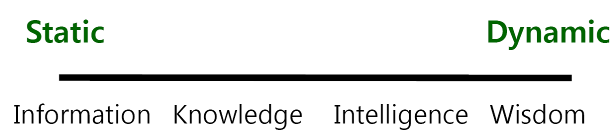

Figure 2. Static-Dynamic context continuum

Human activities could be classified into personal, community, and social activity. In their activities, social relationship and cultural context are very important. Social relationship is relationship between members and u-contents while interacting each others directly or indirectly. Cultural context is a context, which distinguish one community with others, generated by various persons who have different nationality, culture, education. Personal-social continuum is shown in figure 3

Figure 3. Static-Dynamic context continuum

- Real-Virtual (Reality): Real-virtual continuum was presented by Milgram [10].
- Static-dynamic (Context): Context in real world is changing according to time and space. Context can be presented static-dynamic continuum. If context is

	Reality	Context	Activity
Virtual World	virtual	information	personal
Mirror world	virtual	knowledge	social
Collaborative AR	mixed	information	social
Mashup AR [3]	mixed	knowledge	community
Ubiquitous AR	mixed	knowledge	personal
Context-aware AR	mixed	intelligence	personal
U-VR	mixed	wisdom	social
Life logging	real	information	personal
UbiComp	real	intelligence	community

Table 1. comparison between various computing paradigms.

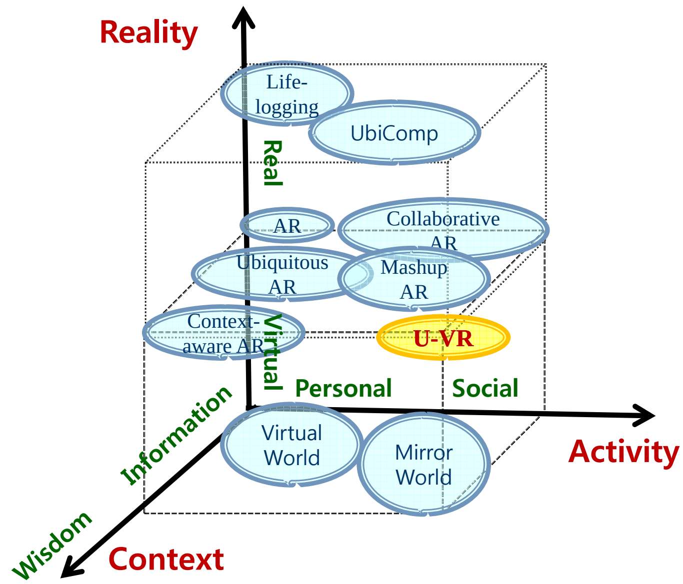

Figure 4. Key dimension of U-VR space

based on static information as user profile, it is static context. If context is based on long-term history with intelligent analysis, it is called dynamic.

- Personal-social (Activity):Activity represents an activity from a single user to large community. The activity describes a social group (community) and initiates social responses of actors in a virtual world to the users associated with the group.

With this three axis, various computing paradigms are classified as shown in table 1. Virtual world has low reality according to Milgram's continuum. Its context is static since it is disconnected from real world. Social activity is rather low. Mirror world has low reality, but it has dynamic context and there is social activity. According to Metaverse loadmap, second life is an example of mirror world. Mirror world is static, but it reflects knowledge about users and social activities of real world [14]. Real world has high reality, but its context and activity are not awared. Life logging records a person's daily activity for smart services. ubiComp supports context-awareness and social activity. U-VR is located between ubiComp and mirror world. U-VR has middle-resolution reality comparing to real world and mirror world. And it is supposed to have rich context and activity. Thus it is the middle of real world and mirror world. Figure 4 shows the results of classification.

Thus, U-VR could be represented as 'socially wise mediated reality'. The 'socially' means that U-VR supports *social activity* by sharing u-contents [11, 6] as well as resources *selectively* to carry out common tasks. The term 'wise' means that it provides a user with intelligent services (u-contents) just-in-time using wisdom according to user's explict request or implicit intention. 'meadiated reality' means that it differs from virtual reality (or augmented reality) in the sense that it allows us to *filter out things* we do not wish to have thrust upon us against our will.

Networked VR or collaborative VR have been developed to support multi-user collaboration. This technology would be applied into real world based on ubiComp infrastructure. At the immersive VR, users can enjoy virtual world over the limitations of time and space. However users, in real world, wear lots of obstructive devices in a limited space. ubiComp enables us to overcome these limitations when fused with VR. Even though VR imitates real world to generate virtual worlds, it does not produce 'real' virtual world. With ubiComp enabled technology, context can be acquired and it could be reflect into virtual worlds.

Several examples which are close to U-VR are shown here. CAMAR (Context-aware Mobile Augmented Reality) applications let user interact with smart objects through personalized control interfaces on their mobile AR devices. It supports enabling contents to be not only personalized but also shared selectively interactively among user communities [16]. Suh et al. presented two applications which are personalized smart object control and context-based contents augmentation and sharing with mobile AR devices. With mobile AR devices in ubiComp environment, a small group of users share content or services which are based on their dynamic context with Mobile AR display.

Garden Alive is an emotionally intelligen interactive garden [4]. It is composed of real garden as a tangible user interface, an evolution and an emotion module, and virtual garden which displays growth and the reaction of virtual plants. This system had monitor based display which showed virtual plant in virtual world and did not care about social community. But it awared user's gestures by analysing images captured from camera.

ARGarden is an augmented edutainment system with a learning companion [12]. It shows a possible approach how an agent(in virtual world) integrate into U-VR. A learning companion is an AR agent which shows the simulation results from virtual world in a augmented environment. Moreover, user's context is acquired while users interacting with an AR agent and it becomes knowledge to select the agent behavior.

4 Future Research Direction: Next U-VR

There are several technical challenges to realize U-VR space. First one is information management/authoring/sharing through total management of ubiComp and virtual worlds by fusing context and augmented reality technology. UbiComp and virtual worlds should be combined so that information and user interaction influence mutually. User experience would be enlarged when user experience in ubiComp and interaction with a virtual world are integrated. And similar to web 2.0 paradigm, open framework should be developed so that users can join the worlds and share their content when they want. Users could design U-VR environments, share the environment and collaborate with others. Moreover, social networking is an essential part to form a user community according to users' context dynamically. Users are able to do their task which are very difficult to perform by oneself since they could share each one's information, experience and content with others.

In future, we should take account of user's participation and contribution in U-VR. We expect that users will be u-contents producers as well as consumers in U-VR, which means u-content are sustainably created and evolved by collaborating and sharing contexts and content each others. Social interaction is also important in the next U-VR. To allow users to create U-VR space, information and users need to be associated with other entities (u-contents) and improved the quality of knowledge and space.

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