Visualization and Management of u-Contents for Ubiquitous VR*

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Abstract. Ubiquitous Virtual Reality, where ubiquitous computing meets mixed reality, is coming to our lives based on recent developments in the two fields. In this paper, we focus on the conceptual properties of contents including definition rather than infrastructures or algorithms for Ubiquitous Virtual Reality. For this purpose, we define u-Content and its descriptor with three conceptual key properties: u-Realism, u-Intelligence, and u-Mobility. Then we address the overall scheme of the descriptor with a Context-aware Augmented Reality Toolkit for visualization and management. We also show how the proposed concept is applied in the recent applications.

Keywords: Ubiquitous VR, u-Contents, Augmented Reality, Context.

1 Introduction

M. Weiser's [14] vision of Ubiquitous Computing (ubiComp) has been being realized in our daily lives. Recently, small computing devices, such as smart phones and tablets, with higher computing powers and equipped with wireless communication capabilities have become available. Additionally, Internet access is available almost everywhere in the world. As a result, the computing paradigm has shifted towards ubiComp, in which computing resources are invisibly distributed everywhere at anytime according to the considerable developments that have been implemented in both Internet infrastructures and computing hardware. In addition to the paradigm shift, a new type of content has emerged by virtue of mashups. For instance, virtual buildings are connected to the corresponding real ones, such as SecondLife [1]. Contents generated by a mashup of geographic data with real images are used in navigation services. The contents that are mainly exploited in Virtual Space have been involved with real environments more and more.

Ubiquitous Virtual Reality (U-VR) is a new computing paradigm established on ubiComp and Virtual Reality (VR) [11]. The basic concept of U-VR is based on the seamless mapping between a virtual world and the corresponding real world. Lee et al. [11] suggested three key terminologies to be used when explaining U-VR.: context, activity and reality. A new concept and representation of contents is

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mandatory in order to support the key terminologies from a viewpoint of contents. For example, mobile Augmented Reality (AR), which overlays the informative contents onto real environments using mobile devices is a representative example of U-VR realizations. However, it is inefficient when used to represent multimedia in mobile AR environments in a conventional way because much relevant information from exterior sensors and services, such as users' profiles and locations, cannot be represented. The contents can exist not only in the virtual world like SecondLife, but also in real environments with the help of AR technologies. In this case, we need to have a hybrid description for the fusion of environmental context and ordinary contents.

A relatively small amount of work has been done to define a new concept of contents for U-VR environments. As an initial work, Oh et al. [13] introduced u-Contents, contents for U-VR. They particularly defined and explained u-Contents with a relevant scenario. Kim et al. [8, 9] reviewed the concept and discussed realization issues. Barakonyi and Schmalstieg [2] proposed intelligent agents for AR with consideration for ubiComp environments. They showed how AR agents help the given task in real applications. [2]'s work has been described from the viewpoint of an agent. For the last few years, standardization groups have researched multi-media applications, such as MPEG-7 (Multimedia Content Description Interface), MPEG-21 (Multimedia Framework), and MPEG-V (Information Exchange with Virtual Worlds), to reflect changes in the computing environment to multimedia contents (MPEG, 2009). Although the previous studies, including those involving MPEGs have dealt with some important issues for content representations and behaviors, there are still ambiguous issues in terms of relating contexts to contents in practical applications with current trends of new computing environments.

In this paper, we present a new definition of contents used in U-VR, which is an extension of Kim et al.'s work [9]. The previous work [9] did not explain practical issues in reference to u-Contents. In this work, we address properties and descriptors of u-Contents for general and practical U-VR applications. First, we review the u-Contents definition and we introduce three key properties: u- Realism, u-Intelligence, and u-Mobility, which are derived from key U-VR terminologies: reality, context, and activity. Then we reveal the relationships among the three properties. Based on these relationships, we discuss the descriptor with Context-aware Augmented Reality Toolkit that facilitates the usage of u-Contents for U-VR applications. We also present preliminary applications to show how the proposed u-Contents are used in U-VR environments.

2 u-Content Definition and Properties

2.1 Definition

We define u-Contents as multimedia contents used in U-VR environments. In particular, u-Contents realistically mediate real space, intelligently respond to user-centric contexts, and seamlessly migrate among selected entities. The terminologies we use for defining u- Contents are as follows:

- *Ubiquitous Virtual Reality* (U-VR): an emerging environment in which a collaborative wearable context-aware mediated reality is realized [11].
- *Mediated Reality*: an environment in which not only visual material can be added to augment real world experiences, but where reality may also be diminished or otherwise altered, if desired [12].
- *User-centric Context*: user-centric information among a variety of contexts in service environments that is interpreted in terms of 5W1H (who, when, where, what, how, and why) for applications [5].
- *Selected Entity*: closely related entities in one community. We follow Dey's [4] definition that the entity can be any person, place, or object.

2.2 Properties

In this section, we describe u-Contents properties in detail. u-Contents have three properties: (1) u-Realism, (2) u-Intelligence, (3) u-Mobility. u-Realism of u-Contents is necessary for the realization of mediated reality. u-Intelligence is a property which makes contents respond intelligently, while u-Mobility covers seamless migration among devices or/and spaces. Fig. 1 shows the three properties of u-Contents and their continuum. We annotate the example of contents in space. The continuum starts from existing multi-media contents and ends at the proposed u-Contents. The scale is determined by the weight of each property. We also address issues that should be resolved in the contents.

u-Realism. u-Realism is a realistic mediation that adds virtual contents into or removes real entities from real space by reflecting users' and environmental contexts. u-Realistic contents are seamlessly registered with a physical space in terms of users' senses. The visual registration overlays the virtual contents onto the real image as if the virtual contents are parts of the real one. The visual sense, in particular, is the most important aspect for seamless registration rather than tactile or auditory senses. That would be why most research in AR mainly concentrates on tracking or registration methods for the stable and accurate visual registration of contents. However, the image formation pipelines of the virtual contents and the real images are basically different so that this difference reduces the realism of the contents. Enhancement of u-Realism is achieved by reducing the differences between the augmented contents and the real scene. Klein and Murray [10] proposed a method that simulates each image formation step in order to reduce visual differences between real images and virtual contents. Besides matching different resolutions between two different contents in each space, we also need to consider the calibration and tracking techniques for seamless registration of the contents. In the continuum, 'decoupled' stage means that the contents are separated from real space. 'loosely-coupled' means that the contents are linked and registered with real entities but they can be distinguished easily. 'seamless' means that we cannot know whether the augmented one is real or not.

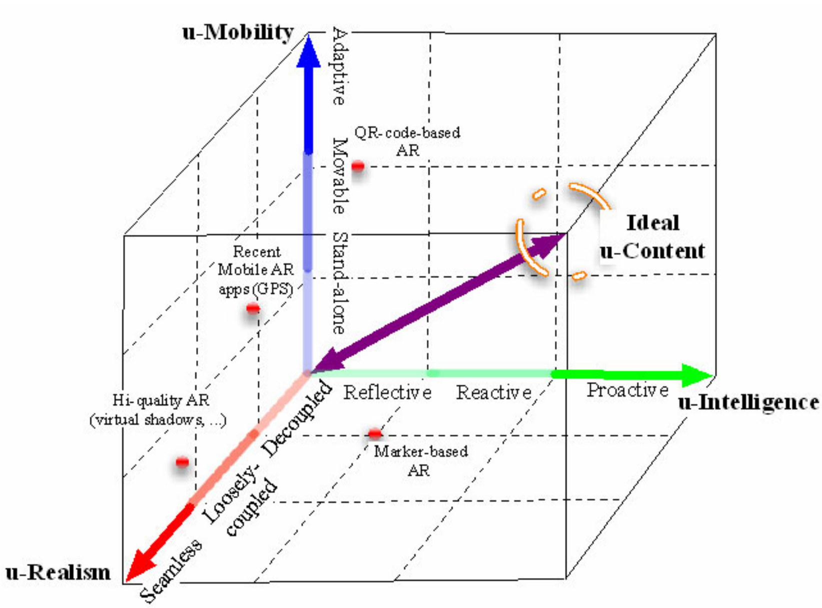

Fig. 1. u-Content continuum; each axis represents three properties, u-Realism, u-Intelligence, and u-Mobility. Each property has three keywords that can explain the level of completion. We map the existing contents or services to our continuum.

u-Intelligence. u-Intelligence is a property in which contents respond to situational information with respect to a user and adaptively change representations according to a user's explicit interaction and implicit states, such as intention, attention, and emotions [3]. The goal of u-Intelligence is to offer users good experiences by providing personalized and responsible contents in U-VR environments. To effectively support personalized experiences, u-Intelligent contents should understand the user's characteristic. Therefore, we need context-awareness to make contents reflect users' contexts. The contents also should perceive the users' interactions and respond to their interactions to allow users to interact with the intelligent contents. To make responsible contents, we should consider the method to decide content's behavior and how to express the content's responses at various situations (e.g., gestures, using image and 3D models, and sound). Then contents have memory to store past experience and the stored experience is used as the source to decide a behavior. In the continuum, 'reflective' responses happen through external factors directly. 'reactive' responses occur through a user, an object, and environments. The contents behavior is determined by processing contexts. 'proactive' responses happen through the prediction and the forecast. The contents memorize its experience and predict situation through the experience.

u-Mobility. u-Mobility is a property that enables u-Contents to move among selected entities. It includes contents that move from one environment to others and to selected entities. u-Contents can be transmitted and translated in accordance with characteristics of u-Mobility. There are three key issues to be considered in order to achieve the u-Mobility property. The first one is content transmission, for example, minimum requirements of network bandwidth and supported protocols. It is necessary to consider the quality of contents and to support real-time visualization. After the transmission, context-awareness, especially environmental context information, is required because u-Contents have to be adapted to the new environment. When we consider u-Contents as multi-media contents that exist in real, virtual, and mixed environments, u-Mobility is necessary to allow the contents to migrate between those environments. The third issue of u-Mobility relates to privacy when contents are shared. When contents move to other users' entities, disclosure and privacy control have to be considered. In order to determine how to share u-Contents with others, personal and social context have to be considered. The social context is realized by user social network among users and properties of u-Contents. In the continuum, 'stand-alone' stage means that the contents can be viewed through homogeneous devices. 'movable' content can be viewed through heterogeneous devices by migration. The last 'adaptive' stage means that we can view the contents in any devices according to dynamic situations through changing properties of content in accordance with target environments or devices.

3 u-Content Descriptor for Visualization and Management

It is important to formulate a context in a consistent way. To achieve consistent context formulation, we have adopted Jang and Woo's [6] Unified Context-aware Application Model (UCAM) in the 5W1H (who, when, where, what, how, and why) form. The proposed descriptor is designed to include not only the general meta-data of a context, but also descriptions of each u-Contents property in the 5W1H form. Representations of contents in the 5W1H form allow U-VR applications to exploit user contexts and environmental contexts in their contents rendering process in two ways, directly and indirectly.

3.1 Descriptor Format

The u-Contents descriptor is a header of u-Contents in a meta-data form. The descriptor defines the characteristics of multimedia contents that are being followed. Extensible Markup Language (XML) is adapted for formatting data. Note that u-Contents descriptors should be written from a contents viewpoint, not an applications viewpoint. Table 1 shows the u-Contents descriptor that classifies the u-Contents into each 5W1H field.

Table 1. u-Content descriptor format in 5W1H

Field	Description
Who	The author (owner) of the contents
When	The last creation or modification time
Where	The position of the contents in a local or a global coordinate
What	Parameters for u-Contents properties: [u-Realism, u-Intelligence, u-Mobility]; Refer Table 2 more in detail.
How	The information about types of authoring tools or context-aware toolkits involved with all fields
Why	The last inferred results obtained from a certain context-aware toolkit

Table 2. Description of 'What' field

Property	Static attributes	Dynamic attributes
u-Realism	**Quantitative information of contents body**: (e.g.) size or dimension of data, total mesh numbers of a 3D graphics model, etc. **5 senses representation:** (e.g.) data representation considering sight, hearing, touch, smell and taste.	**Context history of contents body**: (e.g.) pre-contexts are kept for other applications **Environmental information:** (e.g.) light source positions, temperature, intensity of illumination, etc.
u-Intelligence	**Quantitative information:** (e.g.) the list of possible responses, etc. **Additional information for intelligent responses**: (e.g.) the list of autonomy control rules based on content-specific information.	**User-specific information:** (e.g.) user-specific logics **Environmental information:** (e.g.) a user location, profile, etc.
u-Mobility	**Privilege of u-Contents**: (e.g.) an ownership of u-Contents, privilege of entities sharing the ownership, the level of disclosure and permitted modification. **Requirement for movement**: (e.g.) properties of a target entity: minimum bandwidth of network, supported protocols, etc.	**Community information**: community meta-data (e.g.) members, the goal of the community and relations among the entities. **Movement information**: (e.g.) the movement information is kept for understanding usage of the u-Contents.

The descriptor can be compatible with contents used in common authoring tools except for the 'What' field. The 'What' field, where the properties of u-Contents are mainly described, has two types of attributes, static and dynamic. While the static attributes are not changeable, the dynamic attributes can be overridden whenever the u-Contents are passed to context-aware modules for processing. We rely on these simple criteria of types to classify and to group characteristics of u-Contents. Detailed descriptions of the 'What' field are shown in Table 2.

The proposed descriptor can be extended to represent the meta-data of existing content formats because it includes the information in existing 3D models, videos, images, and so on. There is less possibility of experiencing compatibility problems when using the proposed descriptor in conventional contents and context-aware applications. We found similar approaches in MPEGs. MPEG-7 has a descriptor for audio-visual contents and MPEG-21 has a digital item that is the fundamental unit (meta-data) of distribution and transaction within the MPEG-21. We expect that the combination can be implemented within our descriptor by rearranging detail components.

3.2 Descriptors in a Context-Aware Augmented Reality Toolkit

We display the framework, Context-aware Augmented Reality Toolkit (CART), to validate the usages of the proposed descriptor. The main goal of the CART is to facilitate the usage of various contexts and contents for U-VR applications. Basically, the CART encodes and decodes u-Contents descriptors for U-VR applications. Hence, the CART allows developers to easily fuse AR and context-aware technologies for U-VR applications. The CART consists of a context-aware module and an augmentation- enabled module. Fig. 2 shows how u-Contents are used as one input of CART. When the u-Contents are delivered to CART, the u-Contents descriptor (D) is separated from its body. Then, the descriptor is sent to UCAM to be integrated with all contexts from other services or sensors in the environments. The context-aware module has functions to communicate, integrate, and manage contexts represented in the 5W1H form. UCAM supports three core functionalities: communicator, context integrator, and context manager. The communicator gathers all raw signals from sensors via networks and passes them as preliminary context (*p-context*). In the context integrator, the *p-context* is transformed to the integrated context (*i-context*) by fusing available contextual information. The context manager finalizes the given *i-context* with predefined context and packages them as final context (*f-context*). The *f-context* is transmitted by the communicator and shared with other U-VR applications. The u-Contents descriptor also goes through the same path, and contextual parts are selectively overwritten during the process.

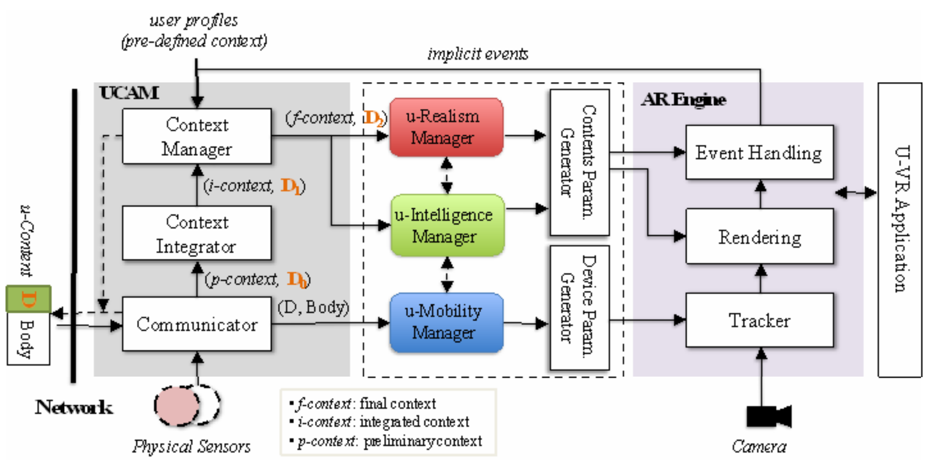

Fig. 2. Flow of u-Contents in the Context-aware Augmented Reality Toolkit

The context cannot be sent to the augmentation module directly because the scales of parameters in the context module are different from the scales in the augmentation module. Consequently, we need another manager in order to change parameters into the scale of AR environments. u-Reolism, u-Intelligence, and u-Mobility managers reverse the scales of parameters. The u-Realism manager extracts the defined information from the f-context and transforms it into rendering parameters. While the u-Intelligence manager determines responses, the u-Mobility manager directly receives contexts from sensors because it is related to low level processing, such as parameters for tracker modules.

4 Examples

In this section, we introduce simple examples and discuss the contents from the viewpoint of the proposed concept. Although the existing examples do not explain the u-Contents concept in all aspects, they can help us understand the u-Contents and properties.

4.1 Virtual Character in the U-VR Room

Fig. 3 shows the snapshots of the corresponding places in real, virtual, and augmented space. If we think this as a preliminary U-VR space, the bluebird in the room could be u-Content. We designed the 3D bluebird model that acts like a virtual pet as the avatar. Basically, the bluebird reacts against two outer contexts, a user's location and environmental sound information. The bluebird has basic predefined behaviors, such as 'fly,' 'walk,' and 'run'. Our assumption is that the user can see the bluebird via a Head-Mounted Display (HMD) or personal mobile devices. When a user enters the room, the bluebird is augmented onto the most silent place, the place furthest from the user. After the user sits on a sofa, the bluebird tries to move toward the user. When a sound such as clapping, is generated, the bluebird returns to the silent place again.

4.2 3D Content Interacting with a Real Object

u-Intelligent contents should respond to users or objects including virtual and real objects, according to situational information. Fig. 4 shows 3D content responses according to situational information. In Fig. 4, there is a 3D augmented character that has predefined behaviors. In Fig. 4(a) and Fig. 4(b), the 3D character perceives a relative position and direction (velocity) of the real toy cart, and determines to push or pull the toy cart. In Fig. 4(c), the 3D character is collided to the toy cart and falls down, as it perceives direction and speed of the toy cart. Because the 3D character considers content's responses to a real object's status, this example is not a perfect u-intelligent content. It should consider how to be aware of user's characteristics and respond adaptively in order to achieve u-intelligence.

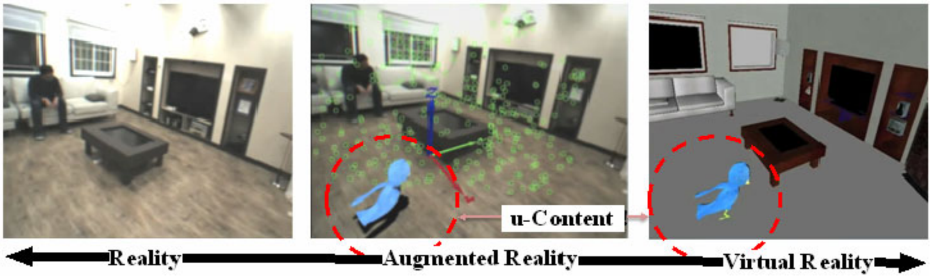

Fig. 3. Virtual bluebird in the U-VR room. The environment has three modes; real, augmented, and virtual reality.

(a) (b) (c)

Fig. 4. 3D character responses according to geometrical and conditional information between 3D character and a toy cart: (a) push, (b) pull, and (c) fall down

5 Conclusion and Future Work

We presented u-Contents concept with the visualization and the management schemes. And also we introduced recent on-going works and their relationship within the u-Contents continuum. Two examples in Section 4 showed the preliminary works to explain our concept. The bluebird example can be mapped 'loosely-coupled', 'movable', and 'reactive' stages. The example dealing with content interaction can be mapped 'loosely-coupled', 'stand-alone', and 'reactive' stages. As one of consecutive works, the standardization activity is initiated [7] to represent mixed reality contents. However, we expect that there will be many practical obstacles to be resolved. One of them is "Contents Ecosystem". In the future, u-Contents and their **Ecosystem** should be discussed together to verify the availability of the proposed contents concept in daily life.

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