2011 International Symposium on Ubiquitous Virtual Reality

Conceptualizing u-Content Ecosystem in Ubiquitous VR Environments

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***Abstract*— In this paper, we propose a concept of u-Content ecosystem in ubiquitous VR environments. We present a definition and features of u-Content ecosystem, and describe its application scenario to interacting with users in ubiquitous VR environments. We also explain the u-Content life-cycle that includes resources, contents production, growth, evolution, reproduction, and destruction.**

Augmented Reality; Digital Ecosystem; Ubiquitous VR; u-Content

I. INTRODUCTION

Ubiquitous Virtual Reality (Ubiquitous VR) has been researched since last 5 years in order to maximize synergies between virtual reality and ubiquitous computing technologies. Ubiquitous VR is defined as a concept of "realizing VR on ubiquitous smart space, i.e., making VR pervasive into our daily lives" [1-2]. Previously, ubiquitous VR has been discussed to define its concept and fundamental properties such as reality, context, and human activity [2]. Ubiquitous VR supports human social connections with user context in mixed reality environments. Hence, a ubiquitous VR environment can be described as a future smart environment for realizing socially wise mediated reality [2-3].

The ubiquitous VR creates and manages u-Content which is a digital content in ubiquitous VR environments [4-5]. The u-Content is a multimedia content which stimulates user's five senses by seamlessly registering virtual contents to a real object through context in ubiquitous VR environments [6]. u-Content involves information of virtual and real spaces linked through context. The u-Content has three properties, such as u-Realism, u-Intelligence, and u-Mobility [5]. As an example of u-Realism, a bluebird, which is a virtual character in a smart room, behaves adaptively according to situation in real space [5]. For u-Mobility property, the bluebird moves from virtual spaces to real spaces and vice versa. The virtual character can directly control a real object and intelligently responds to the real object as u-Intelligence property of u-Contents.

As a fundamental of digital ecosystems, we could experience u-Content in its ecosystem. In ubiquitous VR environments, u-Content is created, maintained, shared, evolved, and consumed with user's participations. To maintain a sustainable u-Content ecosystem in the ubiquitous VR environment, we have several research challenges. The challenges are related to u-Content creation, sharing and distribution among users, consumption, and destruction in ubiquitous VR environments. To resolve the challenges, we should address a design and definition of u-Content ecosystem.

In this paper, we propose a concept of u-Content ecosystem in ubiquitous VR environments. We present a definition and features of u-Content ecosystem, and describe its application scenario to interacting with users in ubiquitous VR environments. Beyond this, we explain u-Content as alive, diverse, interrelated, and evolving; we highlight "contents life cycle" that includes contents creation, distribution, usage, modification/maintenance, archival, and removal.

II. U-CONTENT ECOSYSTEM

u-Content Ecosystem is a new type of ecosystem for u-Content [6]. The u-Content ecosystem is a digital ecosystem that preserves the order of contents which are created, maintained, modified, evolved, or destroyed. It is also a mobile ecosystem in which the mobility of users drives interactions and evolutions [6]. The sustainable u-Content ecosystem supports a multimedia service environment that is created, maintained and evolved by the continuous production, sharing, consumption, extension, and reproduction of contents with user participation in the convergence space of real and virtual spaces.

A content generated from resources go through expansion and evolution step and the content eventually become u-Content with u-realism, u-intelligence, and u-mobility. The u-Content changes and reacts adaptively according to user's movement and state, and environment information. At expansion and evolution, content can have the properties of u-Content and grow for becoming u-Content. The growth is achieved through sharing with other users and the content becomes new content which involves a variety of information (e.g., related text, images, and sounds).

We discuss a food (u-Content) web of passive, primary or secondary consuming, or digesting contents [7]. Depending on local information, passive contents include data sources and ecosystem resources; this classification thus hardly distinguishes passive life-forms (like agents) from environmental resources (like frameworks). Primary consumers feed on passive contents whereas secondary ones feed mostly on consumers: services needing information are primary consumers but services needing inter-service

978-0-7695-4420-5/11 $26.00 © 2011 IEEE
DOI 10.1109/ISUVR.2011.22

support are secondary consumers. Finally, digesters produce u-Content for passive contents based on primary and secondary consumers' activities; they include dedicated monitoring services that produce or modify data.

We describe a concept of the u-Content ecosystem by explaining "contents life cycle" that includes resources, contents production, growth, evolution, reproduction, and destruction. Figure 1 represents a concept diagram of u-Content ecosystem with u-Content life-cycle. Based on this life-cycle, the u-Content ecosystem produces a high quality "u-Content" by using interaction from end-users and digital contents.

In the Figure 1, resources are original form of digital contents (e.g., video, image, sound, text). At this step, people create preliminary resources about their interest. All preliminary resources are retrievable by context (e.g., user/object ID, keywords, tags). At production step, multiple preliminary contents are produced, and registered to specific objects in real or virtual spaces. Incorrect information is literately discarded by a system in ubiquitous VR environments. In the next step, contents are shared among users and extended to real and virtual spaces. For the content growth, a system reacts to user's action according to intelligence of content based on context-awareness. By a sustainable growing, the contents are self-contained and changed to a new type of contents which are adaptable to user's situation. If some contents are not accessible by users, then the contents will destroy. The contents destruction means that the contents and the objects are separated. Also, low-quality, incorrect, or old contents can be destroyed. On the other hand, if the contents are survived, then the contents are changed to u-Content by production, growth, and evolution of the contents. To this end, the u-Content in u-Content ecosystem can be seamless, proactive, and adaptive contents.

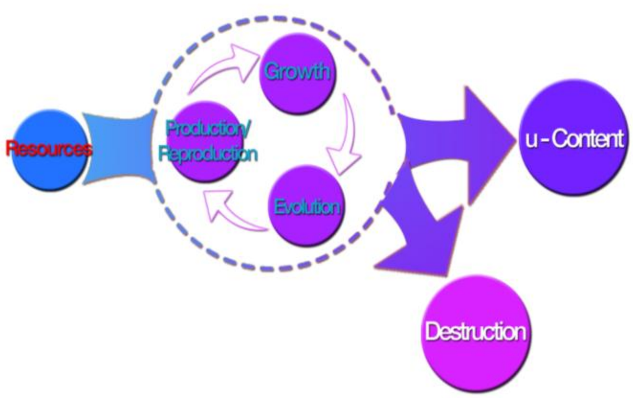

Figure 1. Concept Diagram of u-Content Ecosystem for Contents Life-cycle.

Ubiquitous VR environments can be built based on fundamental concepts of ubiquitous virtual reality [8-11]. Ubiquitous VR environments support link between real and virtual spaces with additional information (aka u-Content). The ubiquitous VR environments provide immersive five sense-augmentation of u-Content. Moreover, the ubiquitous VR environments enable bidirectional interaction between u-Contents on the fly in linked dual space. In such environments, u-Content ecosystem operates u-Content, as shown in Figure 2. In the u-Content ecosystem, u-Content is seamlessly registered to interested objects. The u-Content is augmented as a 3D link of real and virtual spaces. Figure 2 shows a concept of reality continuum among three spaces for the u-Content ecosystem.

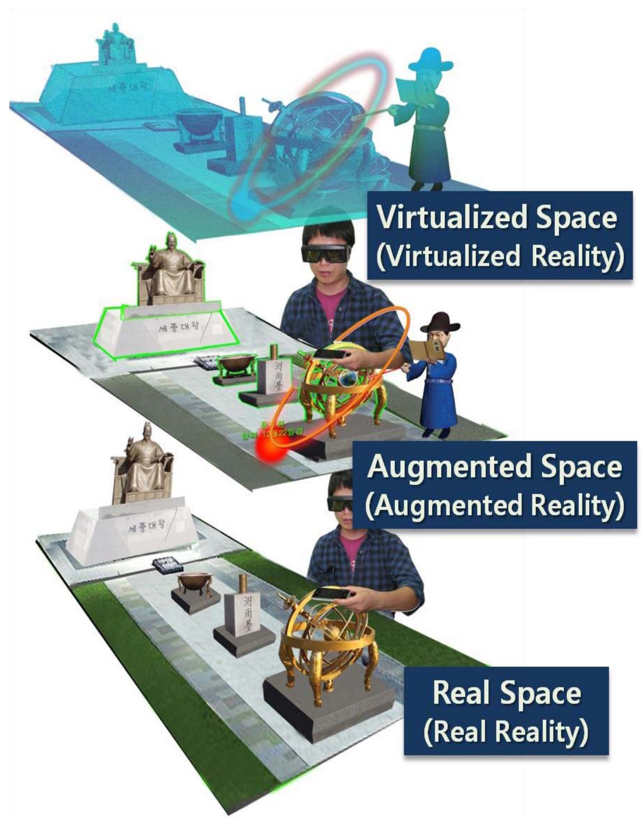

Figure 2. Concept Diagram of u-Content Ecosystem in Ubiquitous VR Environments.

III. FEATURES & REALIZATION

A. *Ecosystem Features*

Digital ecosystems including the u-Content ecosystem exhibit 5 generic necessary features (dynamism, heterogeneity, scalability, evolvability, limited access) and can benefit from 10 desirable ones (adaptability, coherence, privacy-awareness, resilience, robustness, self-configuration, self-healing, self-optimization, self-protection, spatiality). Hereafter, we define, clarify and illustrate these concepts.

Dynamism is the activeness of digital ecosystems in terms of internal configuration, demand, and environment [12]. Changes of internal configuration may be the addition, removal and failure of individual or groups of contents. Changes in demand may be lack of requests contrasted with bursts of activity in e.g. pervasive networks. Environmental activity is marked by variability and unpredictability, for example in the case of the weather and earthquakes.

Heterogeneity is the quality of being diverse, with elements incomparable in kind. This feature concerns contents but also groups (e.g. hierarchical versus flat organization) and individuals (e.g. size, shape, color, pattern).

Scalability is the ability to integrate and network numerous species, individuals and groups [12]. This feature is particularly desirable for pervasive networks, in which numerous tiny/small devices may be deployed to provide local information or to compensate for their low quality/precision [12].

Evolvability is the ability to change over long periods of time. For digital ecosystems, it is ideally enabled in ways requiring little or no re-engineering to integrate innovations and match new requirements [7].

Limited access is the quality of being difficult to affordably find or access [12]. It is usually considered a negative quality because it hampers maintenance and end-of-life processing but may be considered positive. In the case of pervasive networks, limited access implies the difficulty to tether, attend and replenish the resources of some nodes [12].

Generic desirable features for digital ecosystems are as follows. Adaptability is the ability to react to variations and novelty in the environment [7][13]. Coherence is the quality of being clearly and reasonably connected in terms of interoperability and user interfaces. Privacy awareness is the ability to handle privacy, which has been much debated for years in the ubiquitous computing community. It is notably highly desirable for healthcare [14] and e-governing applications. Resilience is the ability to cope with attacks. Robustness is the ability to cope with, or survive to, both internal failures and dynamic environments [13]. Self-configuration is the ability to learn from, and react to, new or recurring situations. Self-healing is the ability to recover from internal faults [13]. Self-optimization is the ability to tune oneself to increase performance (resource-oriented goal-based achievement). Ecosystem-oriented approaches highlight less performance than usual approaches (e.g. top-down engineering) [13]. Self-protection is the ability to prevent, detect, and react to attacks [13]. Spatiality is the property of occupying and relating to a space, typically also of knowing about local and neighboring individuals and resources [7].

B. Realization

To realize u-Content ecosystems, we may integrate many complementary concepts and technologies top-down or bottom-up, relating to all generic features and appropriate desirable features. The top-down perspective is the most common when discussing the realization of digital ecosystems. The top-down ("creativity") method involves specifying, engineering, testing, and deploying technologies.

With a top-down method, [15] proposed to iteratively design digital ecosystems in 5 steps. First, designers define the roles required in the ecosystem, considering information and transaction flows, and then define types of contents that may partially or completely fulfill one or several roles. Second, designers define inter- and intra-contents collaborations, determining the behaviors (self-organization for autonomy, predetermined for control, hybrid for heterogeneous needs) required by each contents to effectively and efficiently function together, then defining a matching optimal ecosystem structure (chaotic, orderly, semi-orderly). Third, the designers make the contents intelligent, providing knowledge bases in simple cases or ontologies in complex cases, and evaluating the results technically, practically or mathematically. Fourth, the designers protect the ecosystem, identifying and addressing issues, setting boundaries, encoding this knowledge, and equipping contents with this knowledge; crucial issues include authentication, availability, confidentiality, non-repudiation, integrity, compliance, servicing, and dedication to ecosystem-level purposes. Fifth, the designers enable, improve, or construct individual contents by identifying features of the contents.

IV. APPLICATIONS

In this section, we explain a possible application scenario for next-generation experimental education in ubiquitous VR environments, as shown in Figure 3.

In *Sejong Street, Seoul, Republic of Korea*, a user wearing a HMD can link between real space and virtual space by looking real objects (e.g., King *Sejong*, armillary sphere, rain gauge, altitude dial, etc.), control augmented objects (e.g., a virtual clock connected to the armillary sphere) using a mobile phone and simulate movement of constellation or weather changes through immersive five-senses augmentation.

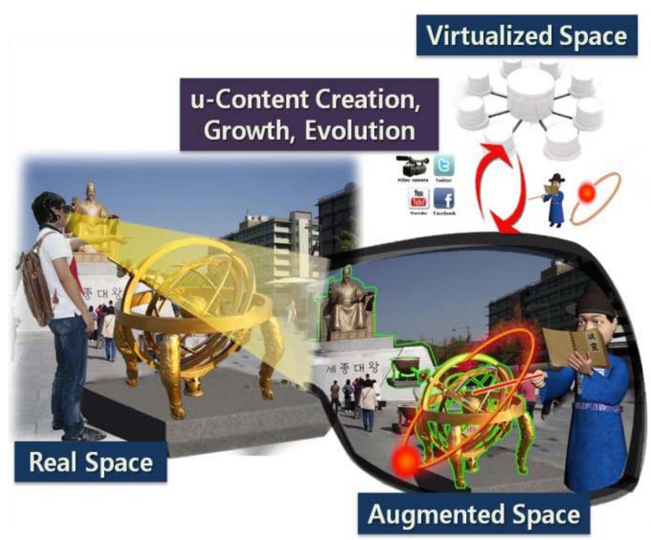

Figure 3. Application scenario for next-generation experimental education in ubiquitous VR environments.

In addition, users in real space can also make and share information (real-time personal broadcasting, social media) with users in virtual space on the fly through bidirectional interaction linking dual space. Moreover, for more effective simulation, intelligent AR contents and character are augmented and provides additional explanation for the simulation.

The scenario could be applied to other time/space transcended smart work (remote immersive conference), next generation experimental education (Science, Math, English, Art, History, etc), immersive simulation (climate, ecology, environment, military, urban planning, architecture, disaster, etc), video based information survey (traffic, security, etc), medical information augmentation, immersive entertainment.

V. CONCLUSION

In this paper, we proposed a new type of digital ecosystem for u-Content that is a circular structure consisting of the correlation among user intervention, environmental impact, and development of digital contents. The u-Content ecosystem was defined as a sustainable digital ecosystem that preserves the u-Contents which are produced, maintained, shared, evolved, or consumed by means of users' participation in ubiquitous VR environments. Finally, we expect our proposal to lead to self-emergence at both the micro (better contents and more interesting links between contents) and macro (prosumers) levels.

ACKNOWLEDGMENT

This research is supported by Ministry of culture, Sports and Tourism (MCST) and Korea Creative Content Agency (KOCCA), under the Culture Technology(CT) Research & Development Program 2011, and the Global Frontier R&D Program on <Human-centered Interaction for Coexistence> funded by the National Research Foundation of Korea grant funded by the Korean Government(MEST) (NRF-M1AXA003-20100029751).

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