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A Study on Capturing Learning Data from Virtual and Mixed Reality Contents Through Data Collection API

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Abstract: In the fourth industrial revolution, which is called the intelligent information society, virtual and mixed reality contents and personalized learning that can maximize the learning effect are attracting attention. By developing Virtual Reality (VR) and Mixed Reality (MR) contents according to the learning topics, and learning activities characterized, immersion and authenticity of learning can be expected more than the current multimedia resources, such as videos and images. Furthermore, it can provide customized learning path by applying learning analysis technology to data using virtual and mixed reality contents which can induce the interest and attractive of learner. In this study, we introduce a method of extracting learning data generated from virtual and mixed reality contents, and converting it into a standardized learning data format for learning analytics.

Keywords: Virtual Reality, Mixed Reality, Learning Analytics, Data Collection, Standard

1. Introduction

Now that our society and economy is increasingly dependent upon knowledge and information, there are increasing attempts made, both in and outside Korea, at incorporating virtual reality (VR) and mixed reality (MR) technologies into the education curricula and foster active ecosystems for innovation in these technologies.

The International Organization for Standardization (ISO) and experts worldwide resort to Paul Milgram's "Reality-Virtuality Continuum," first introduced in 1994, to explain the distinction (or continuum) between Virtuality and reality. As Figure 1 shows, virtuality can be understood as forming the opposite endpoint of the continuum of reality. The part of the continuum that falls in between these two extremes can be summed up as mixed reality. Mixed Reality can be roughly divided into two subtypes, i.e., Augmented Reality (AR) or Augmented Virtuality (AV), depending on which endpoint on the spectrum it is closer to (Lee & Cho, 2017).

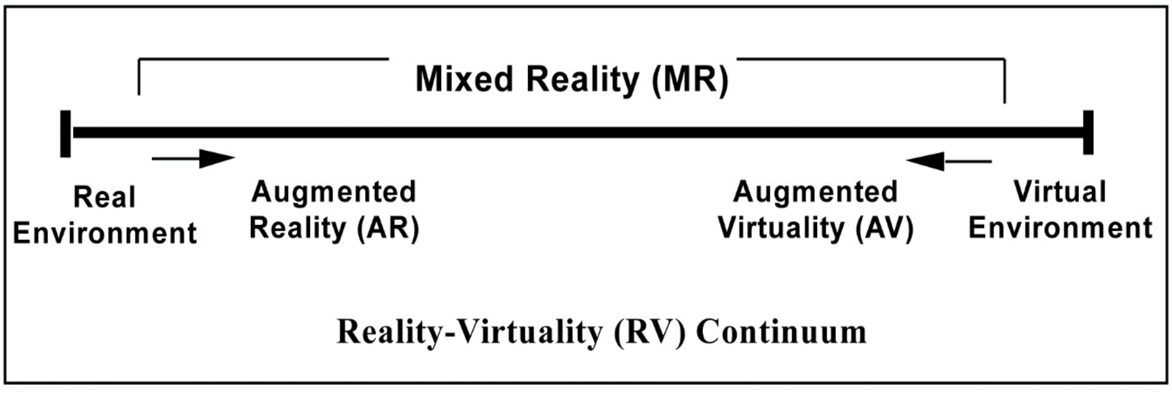

Figure 1. Reality-Virtuality Continuum (Paul, Takemura & Utsumi, 2007).

VR and MR technologies allow users to interact much more actively with their content by providing a wider range of newer interfaces and functions than the general web or mobile environments. In order to effectively utilize this in the field of education, data related to learning activities should be collected. It is possible to improve learning ability through the application of learning analytics technology and to recommend personalized learning resources by diagnosing the learner's knowledge level and competence. We expect to encourage more creative learning activities and participation.
To this end, we explain the xAPI and IMS Caliper, which is known as the representative data collection system in the field. Next, we look at the Learning Data Collection System and the Learning Analytics Reference Model. Finally, we suggest how to extract learning data from the virtual and mixed reality contents.

2. APIs for Collecting Learning Data

As there are diverse learning environments—platforms and software programs—supporting students' online learning, a number of standardization organizations have developed application programming interfaces (APIs) for profiling and collecting learning data. We introduce two main examples.

2.1. Experience API (xAPI)

Advanced Distributed Learning (ADL) under the U.S. Department of Defense developed the Sharable Content Object Reference Model (SCORM), one of the e-learning content standards. It has developed the Experience API, which is a data collection system, and is called xAPI. In 2008, we started to needs analysis and developed a beta version under the name "Thin Can API" in 2011. After that, it gave an official name for the Experience API in 2013 and released the current version 1.0.3.

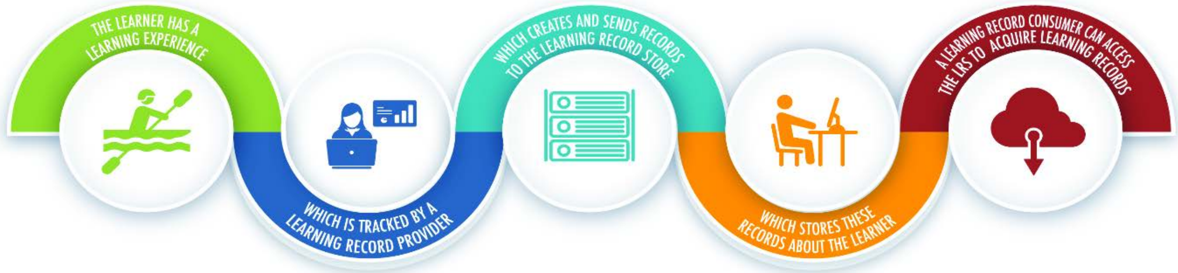

Figure 2. xAPI Data Flow.

xAPI defines data structures in ways that can explain users' activity streams systemically across diverse domains, including education. xAPI is mainly used, in education, to collect log-type data that are generated when SCORM-based applications are in use. The data collected by xAPI are gathered into a designated learning record store (LRS) and being transmitted to a learning management system (LMS) or transferred to reporting tool through the analysis (Cho, 2016).

2.2. IMS Caliper

IMS Caliper, developed by IMS Global Learning Consortium, a leading organization for developing educational standards, consists of metric profiles and an open-source API that collect learning activity data.

IMS Caliper defines measures to be used to identify and collect data on different types of learning activities so that the accuracy and efficiency of data collection can be maximized. As Figure 3 shows, there is a wide range of learning activities, such as evaluation, media application, assignments, and debates. The types of learning activities will only increase in the future.

Figure 3. Learning Activities Defined in IMS Caliper Version 1.1 and Future Learning Activities To Be Developed.

IMS Caliper applies its standard only to gather data and the transmitted to event stores. Although analysis and reporting are central elements of learning analytics services, data-collecting APIs do not apply their standards to these elements (Cho, 2016).

3. Reference Models of Learning Data Processing and Analytics

3.1. Learning Data Binding Structure

Both xAPI and IMS Caliper use a triple structure for describing data. This triple structure, which the Resource Description Framework (RDF) uses to express concepts, consists of subjects, predicates, and objects. Additional information consists of contextual information on the types of applications in use, timestamp, courseware, learning outcomes, and objects generated by users, and is expressed by enveloped data (Cho, 2016).

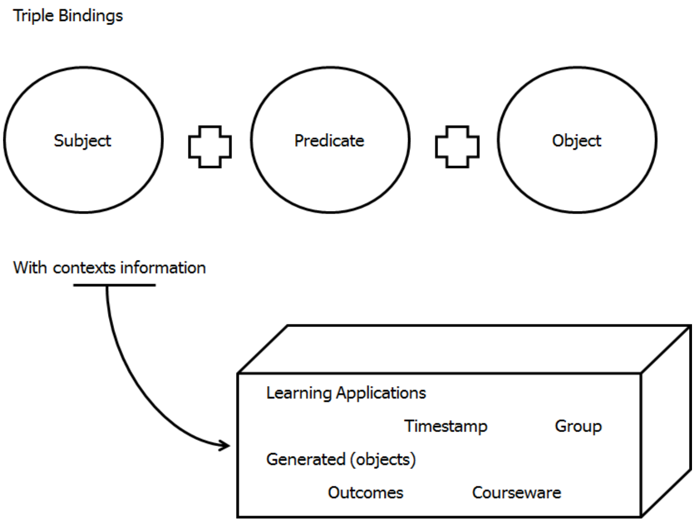

Figure 4. **Learning Data Expression Structure.**

3.2. Learning Data Flow

Figure 5 summarizes the process in which learning data are generated and gathered together in a designated data storage. Both xAPI and IMS Caliper use this process to collect and transmit data. But additional functions must be inserted in between storage systems in order to convert different formats and content of the transmitted data into consistent forms (Cho, 2016).

The learning environment is classified into each different environment, according to the data collection API. xAPI and IMS Caliper Sensor define and collect the data they gather in different ways. Data collected by IMS Caliper are transmitted into event stores, while data collected by xAPI's recipes are gathered into LRSs. There is a data mapping and matching process between the two repositories, through which the data are transformed.

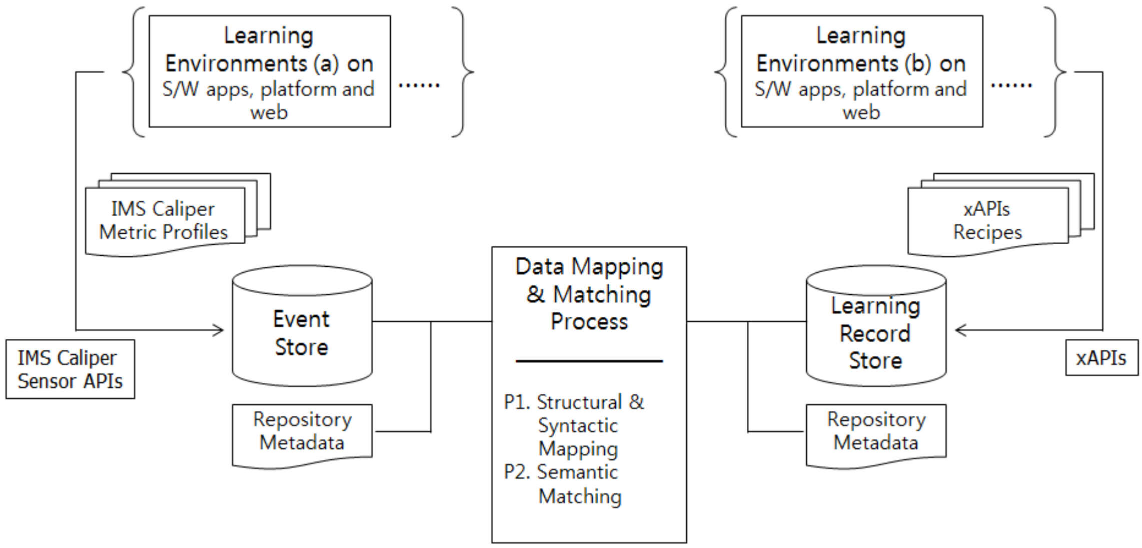

Figure 5. Learning Data Flow.

3.3. Reference Model of Learning Analytics

The workflow featured in a reference model of learning analytics consists of teaching and learning activities, data collection, storage and processing, analysis, visualization, and prescription and advice. Figure 6 shows a top-level reference model of learning analytics.

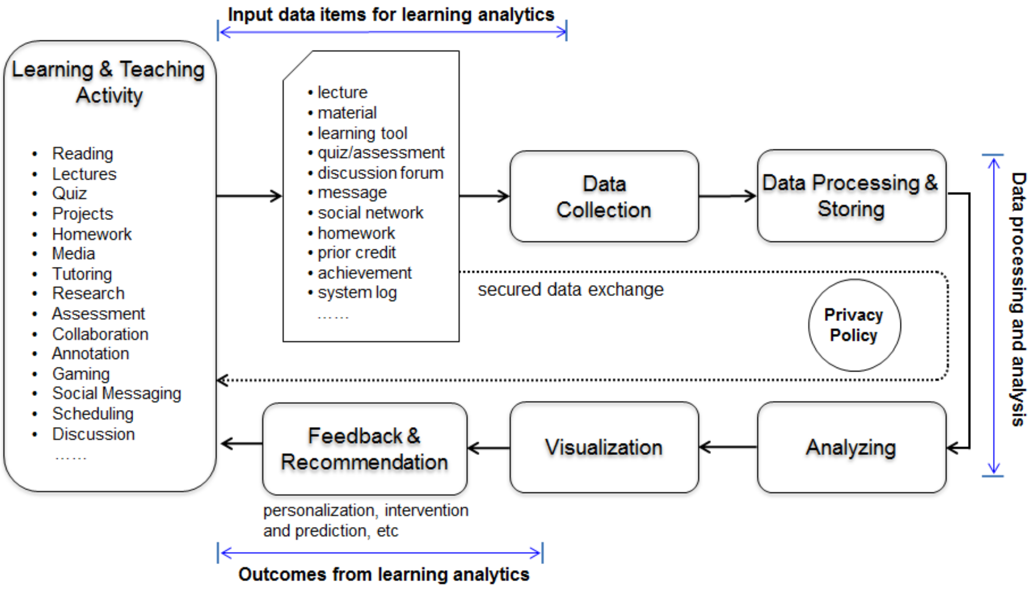

Figure 6. Reference Model of Learning Analytics: Workflow (Cho & Lee, 2016).

All processes can control and exchange data according to the privacy policy. The types and models of data used in learning analytics are standardized, unlike data used in other types of analytics. Standard APIs like xAPI and IMS Caliper can therefore efficiently collect the needed data.

4. Capturing Learning Data from VR and MR Content

4.1. Characteristics of VR and MR

VR uses virtual images throughout, including virtual objects, backgrounds, and environments. MR, on the other hand, overlays real images or backgrounds with 3D virtual images or objects. VR and MR may appear similar at times, but they can be clearly distinguished by the extent to which reality is involved. VR computer games, for example, feature characters representing real players engaging in games against the characters of other players against a virtual backdrop. MR games, on the other hand, involve real players engaging in games against virtual characters. VR thus tends to be more immersive and MR tends to be more real.

4.2. Examples of VR and MR

We introduce two main examples of VR and MR applications for education.

Example 1: Apollo 11 VR EXPERIENCE
"Did you dream of becoming an astronaut or a space scientist as a kid?"

Apollo 11 VR EXPERIENCE, from Immersive VR Education, provides an educational documentary and virtual tours of the Moon using the video- and audio-recordings kept by the National Aeronautics and Space Administration (NASA). With this program, students need no longer confine their role to mere spectators or audiences, as they can actively explore the same scenes and landscapes encountered at the historic landing of Apollo 11 in 1969. The program enables students to fly to the moon aboard Apollo 11 with (virtual) Neil Armstrong any time they want. Students can also move the command ship and the landing vessel to land on and explore the surface of the Moon (Lee & Cho, 2017).

Figure 7: Apollo 11 VR EXPERIENCE.

Example 2: Microsoft HoloLens

"At times, the right mixture of reality and virtuality can be far more charming and effective than complete virtuality."

Microsoft's HoloLens uses MR technology to enable students to view the hidden internal parts of the body, such as the bones, nerves, muscles, and internal organs, and how they function while alive even without dissecting the human anatomy themselves. Of course, perfect VR can be used to provide similar lessons in biology and anatomy. Microsoft's HoloLens, however, is especially effective because it presents such rarely seen information precisely in the mundane settings of the real world. The MR objects seen through HoloLens strike students as more real and natural than some graphics-generated images, and therefore effectively support biological and anatomical learning. Because it also allows multiple users to interact with one another in real-world spaces with respect to the virtual objects they together see, it can also support human-to-human communications (Lee & Cho, 2017).

Figure 8: Exploring the Human Anatomy Using Microsoft's HoloLens.

4.3. Capturing Learning Data

AR and VR technologies allow users to interact much more actively with their content by providing a wider range of newer interfaces and functions than the general web or mobile environments. In order to make the most effective use of these technologies in education, it is critical to gather data on learning activities, and use these data in the analysis of students' learning attitudes and behavior.

Learning analytics is already widely employed in education to gather and analyze data on a wide range of learning activities, including learning time, evaluation results, debates, media operations, and the use of educational applications. The analysis rendered thus are used to provide individual students with customized assessments and advice. It is therefore important to capture and use the data generated by using VR and MR for education in learning analysis.

In this study, we design a procedure and method for capturing learning data from VR and MR applications used and for converting these data into proper and consistent formats for learning analytics. VR and MR applications are generally used with exclusive devices or mobile devices. Much of the data, except for those pertaining to rendering, remain concealed and resistant to capturing and review. We thus use the xAPI standard to capture standardized forms of data from VR and MR applications. We then convert these captured data into the IMS Caliper standard so as to discern the in-depth meanings they provide on learning activities.

The process of capturing learning data from VR and MR applications used and converting them into standardized forms for transmission is shown in Figure 9.

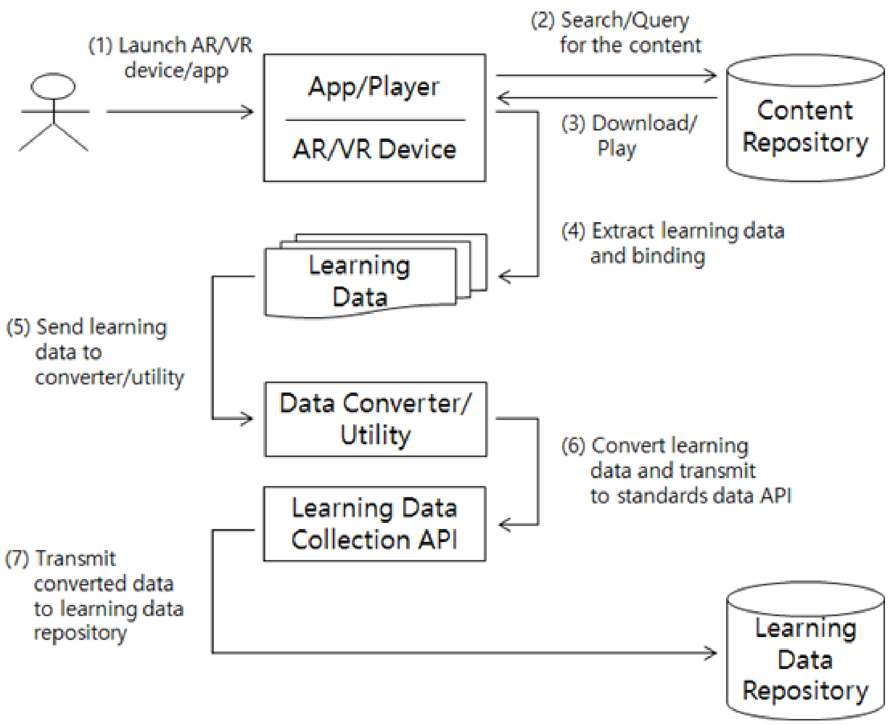

Figure 9: VR and MR Learning Data Capturing Flow.

The data capturing and processing process illustrated in Figure 9 can be explained as follows.

(1) The user runs a given VR or MR application on his/her device.
(2) The search results and queries that the user has entered are transmitted to the content repository, and the content list is viewed.
(3) The data on the content list are downloaded and the user replays the downloaded data on his/her device.
(4) The learning data generated by the user's use of the application are captured and bound.

(5) The captured learning data are then transmitted to the data converter or utility program. The data converter includes the classes of the learning data generated, the structural and syntactical mapping instance tables, and the semantic instance tables that express the meanings of learning data according to the given ontological rules. Here identification numbers, such as URIs, are assigned to the classes and properties of data profiles to complete the identification system and process.
(6) The transmitted data are then converted into standard forms (xAPI, IMS Caliper, etc.).
(7) The standardized data are then transmitted into and stored in the learning data repository. The repository checks the conformity of the stored learning data to the predefined rules on classes, properties, and semantic instance values. Only conforming data are stored, and non-conforming ones are excluded.

5. Conclusion

By capturing learning data generated by the use of educational VR and MR applications and converting them into proper formats for learning analytics, we can provide learning data we use.

Systemic collection of data is a critical success factor for accurate learning analytics. The inclusion of inaccurate or vague data into giving datasets will necessarily increase the amounts of efforts and time involved in processing and refining data, thus making it difficult to provide effective real-time analysis. That is why it is important to standardize the data collection systems (Cho, 2016).

By applying VR and MR applications and technologies that can stimulate students' interest and engagement and using effective learning analytics, we will be able to find more high quality learning pathways that keep students motivated to learn.

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