ISO/IEC JTC 1/VR AR for Education Ad Hoc Group

2019-8-12

White Paper

Guidelines for Developing VR and AR Based Education and Training Systems

Executive summary

Education and training is evolving at an accelerated rate along with an increased level of integration with ICT systems. Growth in this area will only continue. Education and training integrated with ICT systems is progressing in two ways: one is in the use of virtual digital information without the use of devices, and the other is in the use of both virtual digital information and sensor devices. Both types of education and training will expand based on the advance of ICT including virtual reality (VR) and augmented reality (AR). Note that mixed reality (MR) is a mix of real and virtual reality and is therefore presumed to be included in the continuum of VR and AR in this paper.

Virtual education and training systems are typical applications for systems integration. They are based on the technologies of VR and AR with sensors. Although education and training areas are diverse, virtual education and training systems can have unique information modeling, as well as common functionalities. Common teaching and learning technologies for virtual education and training systems can be determined by categorizing use cases for education and training based on VR and AR.

Education and training has been integrated with digital information systems and the development of education and training information systems is increasing. It is presumed that application-dependent methods are being used since the areas of education are vast and simulating education and training with a unified procedure may not be feasible. However, from the point of view of ICT integration and information modeling, virtual education and training systems can be developed based on a systematic design approach with standards. In this paper, a systematic standards-based design approach that can be used as a guideline for developing virtual education and training systems in various areas is provided.

Acknowledgements

This white paper has been prepared by the JTC 1 VR AR for education ad hoc group, whose members include:

Myeong Won Lee (U. of Suwon), JTC 1 SC 24, Convenor of the JTC 1 VR AR for education ad hoc group

Teruhiko Suzuki (Sony), JTC 1 SC 29

Erlend Overby (Hypatia Learning), JTC 1 SC 36

Charles Whitlock (BSI), JTC 1 SC 24

Koohyar Minoo (Consultant), JTC 1 SC 29

Brian McAuliffe (HP), JTC 1 Ireland

Yong-Sang Cho (i-Scream Edu Inc.), JTC 1 SC 36

Byoung Nam Lee (ETRI), JTC 1 Korea

Jake V. Th. Knoppers (Infoman Inc.), JTC 1 SC 36

Yoshikazu SEKI (AIST), JTC 1

Peter Ryan (DSTG), JTC 1 SC 24

Christophe Mouton (EDF), ISO/TC 184/SC 4/JWG 16 and JTC 1 SC 24

Kate Grant, JTC 1 UK

Wang Cong, JTC 1 China and JTC 1 SC 24

Table of Contents

List of abbreviations

3D	3-Dimensional
AFX	Animation Framework eXtension
AR	Augmented Reality
ARAF	Augmented Reality Application Format
BIFS	BIFS: BInary Format for Scenes
DRM	Data Representation Model
EDCS	Environmental Data Coding Specification
HDR	High Dynamic Range
HEVC	High Efficiency Video Coding
HNSS	Hybrid Natural/Synthetic Scene
H-Anim	Humanoid Animation
ICT	Information and Communications Technology
IT	Information Technology
ITLET	IT-enhanced Learning, Education, and Training
JPEG	Joint Photographic Experts Group
LET	Learning, Education, and Training
LOA	Level of Articulation
MAR	Mixed and Augmented Reality
MLR	Metadata for Learning Resources
MPEG	Moving Picture Experts Group
MPEG-A	Augmented Reality Application Format
MR	Mixed Reality
OMAF	Omnidirectional Media Format
SAI	Scene Access Interface
SRM	Spatial Reference Model
STF	SEDRIS Transmittal Format
VR	Virtual Reality

SEDRIS	Synthetic Environment Data Representation and Interchange Specification
VRML	Virtual Reality Modeling Language
X3D	Extensible 3D
XML	Extensible Markup Language

1. Introduction

Virtual education and training systems are typical applications for systems integration. These systems use virtual reality (VR) and augmented reality (AR) with sensors for education and training. Although education and training areas are diverse, virtual education and training systems can have unique information modelling requirements, as well as common functionalities. Common teaching and learning technologies for virtual education and training systems can be determined by categorizing use cases for education and training based on VR and AR.

VR and AR based virtual education and training systems have requirements related to learning and teaching technology, representation, exchange, data, and device, in the following ways. First, existing learning and teaching technology should be extended and integrated with the use of VR and AR technology. Based on changes in learning and teaching methods when using VR and AR, requirements for interaction and simulation should be added. Second, 3D visual and interactive representation should be provided to enhance the effectiveness of education and training. 3D simulation is an important aspect in representing educational information and in understanding education and training content. Third, information for education and training should be exchangeable over heterogeneous computing environments so that users can access education and training information anytime, anywhere. Fourth, information data for education and training should be organized and transferred securely and without delay. Fifth, interfaces for interacting with devices and sensors should be included. Safety should also be a consideration when using larger devices, such as in industrial education.

This paper provides guidelines for developing VR and AR based education and training systems to meet the requirements listed above. The guidelines include concepts, information modelling architecture, standards based functional components, and implementation components for virtual education and training.

2. Scope

This white paper describes guidelines for developing virtual education and training systems based on VR and AR technology. It is intended to illustrate information modeling with standards that can be used for virtual education and training systems. It provides procedures or methods for developing 3D virtual education and training systems based on ISO/IEC JTC 1 standards. It also provides a systematic approach to developing applications for systems integration areas. Virtual education and training systems based on VR and AR are typical examples of systems integration applications.

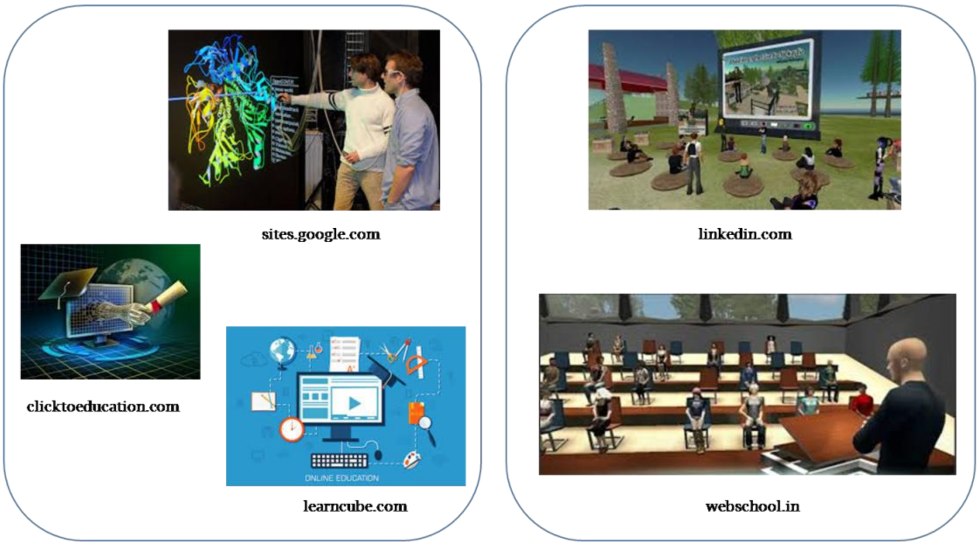
This white paper includes several topics that relate to virtual education and training systems. First, concepts of VR and AR based education and training are defined. Second, it describes software and application development technology necessary for virtual education and training systems. Third, standards for VR and AR information generation, transfer, and exchange when developing the systems are described. The information model and architecture of virtual education and training systems are specified as basic standards concepts. Fourth, components for organizing virtual education and training systems are discussed based on the standards concepts. Fifth, standards based application development technology and software interfaces between computers and devices are described. Finally, implementation components for developing VR and AR based education and training systems are included.

This white paper excludes device hardware technology for virtual education and training systems.

3. Concepts

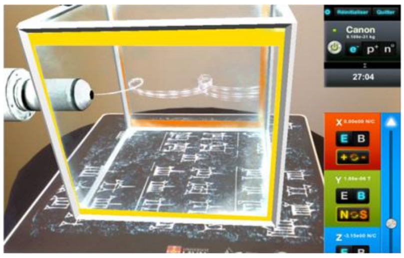
Virtual education and training is a representative area for the application of systems integration technology. It is based on MAR concepts[1] which include VR and AR. It includes computer simulated education and training processes, and provides for repetitive and empirical learning in immersive virtual environments.

Use cases for virtual education and training systems can be classified as two types, each defined slightly differently. The first is virtual education, which facilitates education via digital information and devices based on ICT including VR. Virtual education systems include online and offline learning and teaching (Figure 3.1, 3.2). Online virtual learning and teaching are wholly accomplished using computing devices in virtual environments, while offline virtual learning and teaching partially uses digital information and virtual environments. The latter case corresponds to an environment where both students and teacher are present in a classroom and where digital information with virtual environments is sometimes used.

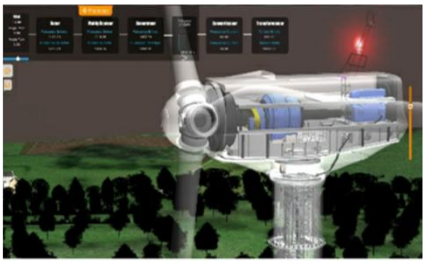


Education content and materials | Learning and teaching

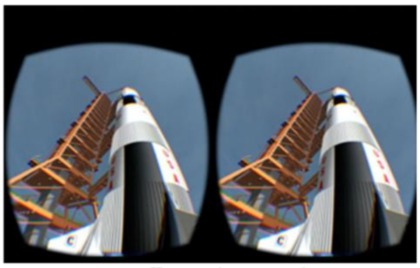
Figure 3.1 Virtual education systems (1)



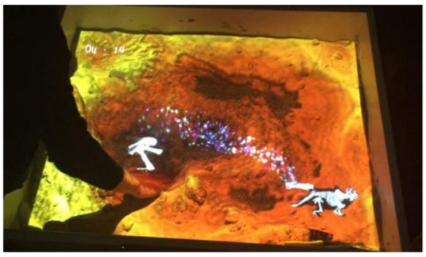
Movement of charged particles (AR case)
(Canada)



Project EAST Consortium (VR case)
(France)



Apollo 11 (VR case)
(VR Experience)



SendDraft (MR case)
(Korea)

Figure3.2 Virtual education systems (2)

The second type refers to virtual training systems that make use of real world sensor devices along with virtual environments. It is based on MAR virtual environments with training devices, sensor information, and interactions with sensors (Figures 3.3, 3.4).

Driving simulation
(Road Traffic Authority, 2013)

CycleOps virtual training
(CycleOps, 2012)

Boeing CRVS
(The Boeing Company)

Military training
(STI, USA)

Figure 3.3 Virtual training systems (1)

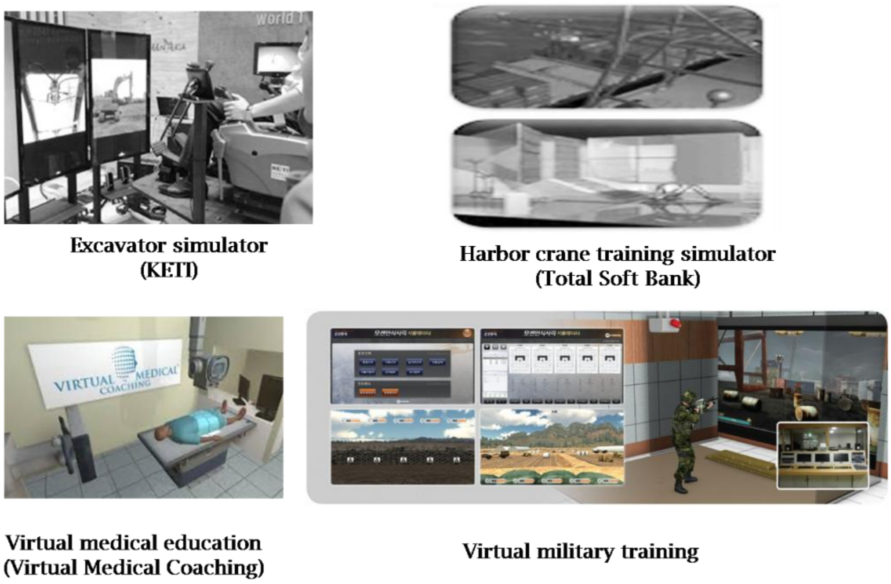


Figure 3.4 Virtual training systems (2)

Virtual education and training systems are computer hardware and software integrated systems for virtual education and training in virtual environments. They can include implementation of education and training simulation in 3D virtual environments. When simulating education and training information, sensor data from education or training devices in the real world can be imported to and be represented in a 3D virtual environment. All virtual education and training systems can have similar system functions, so systems integration methods for virtual education and training can be standardized. As a result, standardized systems integration guidelines can be drawn on and used when developing various virtual education and training applications.

Figure 3.5 shows the phases of systems integration necessary when developing virtual education and training systems in various areas. The first phase represents a systems integration process including VR, AR, and 3D simulation based on representing information for virtual education and training. In the second phase, real world sensor information can be included and simulated. The third phase represents the necessity of standardized systems integration so that common processes for integration can be applied to all virtual education and training areas.

For the first phase, while virtual education and training systems is one typical application area amongst many, these applications are, in fact, MAR applications. Figure 3.6 shows the whole range of mixed reality, including augmented reality, and the relation between virtual education and training systems and mixed and augmented reality. It shows that virtual education and training systems are the result of implementing 3D simulation with sensors in MAR environments.

For the second phase, sensor based virtual education and training systems integrate physical sensor devices (or just physical sensors) and their functionalities in 3D virtual environments. A physical sensor device means a physical device that includes sensors such as a simulator. The appearance and physical properties of a physical sensor can be represented in a 3D virtual world. In addition, the physical properties and events for education and training can be controlled and managed in the virtual world.

In order to provide the capability to represent and simulate physical sensors in education and training systems, the systems require the following: representation of physical sensors, visual and functional properties of each physical sensor, physical properties of each physical sensor, control of a physical sensor's data stream, and an interface for controlling physical sensors in a 3D scene.

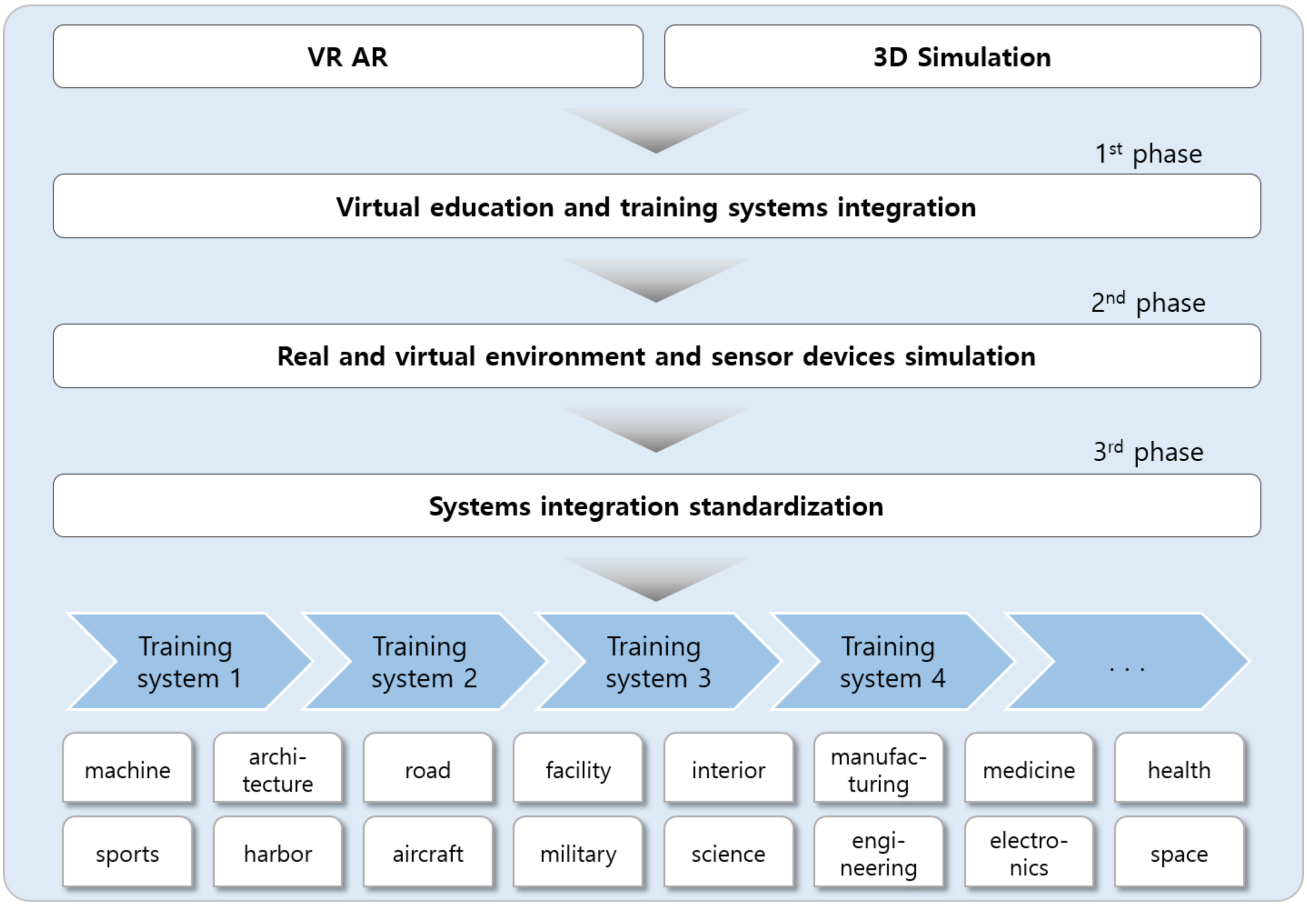


Figure 3.5 Virtual education and training systems, and systems integration

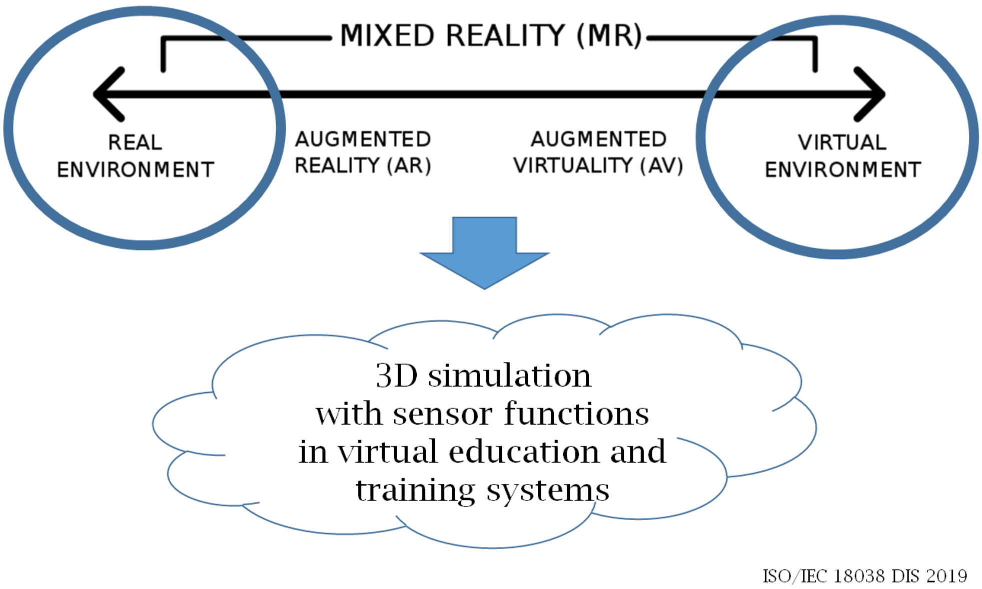


Figure 3.6 Mixed reality, and virtual education and training systems

Figure 3.7 shows a physical sensor representation model that can be used for implementing virtual education and training systems in 3D virtual worlds. It consists of a sensor simulated MAR world, a spatial mapper, and an event mapper. A simulated sensor MAR world organizes MAR content with scene composition. ISO/IEC 18038 DIS describes details of the model[2].

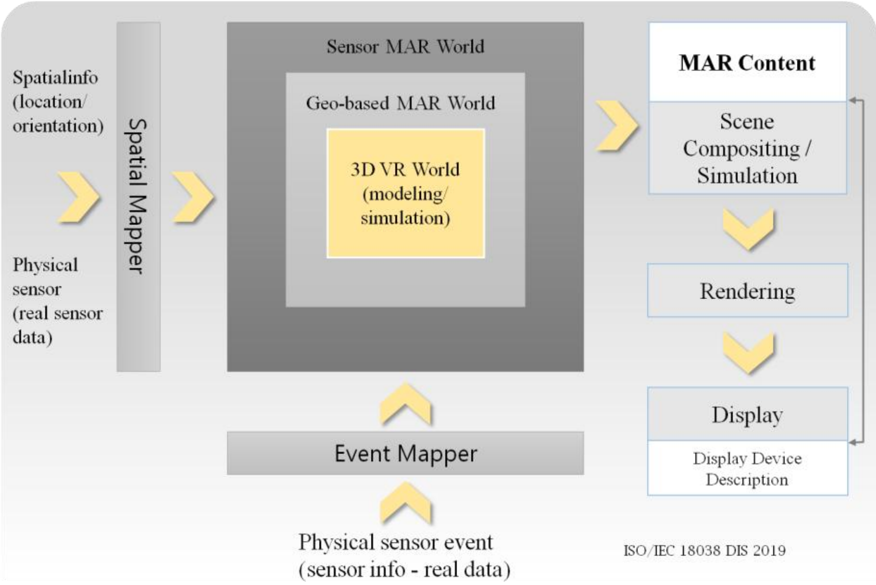


Figure 3.7 A sensor representation model in a MAR world

The sensor representation model can be used as a basis for implementing virtual education and training systems. The middle of the figure shows 3D scene information modeling for education and training, while at the left is a spatial mapper that recognizes location and orientation. At the bottom is an event mapper that sends sensor information to the 3D scene. Finally, at the right is the rendering and display of the 3D scene.

The framework for virtual education and training systems consists of various components (Figure 3.8). In the figure, the upper half represents various applications of virtual education and training, while the lower half shows virtual training system components. The middle part in the lower half represents the required technologies for the systems. Education and training content can be input to the systems via the combination of a virtual simulation platform and an experience and knowledge database. Simulator software should be provided for education and training. This includes a simulator control management tool, operations management, and evaluation.

When developing virtual education and training systems based on the framework, the following technologies, in addition to VR and AR, are needed:

- Content creation and manipulation
- Information modeling
- Visualization and simulation
- Sensor representation
- Real world representation
- Graphical user interaction

Content creation and manipulation should include definition, storage, retrieval, transfer, and interaction with teaching and learning knowledge. Since learning and teaching technology can be combined with knowledge databases, guidelines on how to create and manipulate knowledge databases of education and training content should be provided. In addition, user interfaces for learning and teaching should be standardized. Information modeling using VR and AR is necessary to be defined and implemented for virtual education and training systems so that content in knowledge databases can be simulated in virtual environments. How to define and represent education and training information in relation to VR and AR should be analyzed. Visualization and simulation should include 3D representation, and simulation methods or procedures for education and training. Sensor representation should include real world sensor information used for education and training. Real world representation should include real world physical objects represented in virtual environments. Graphical user interaction should include types and usage of interfaces with virtual environments during education and training.

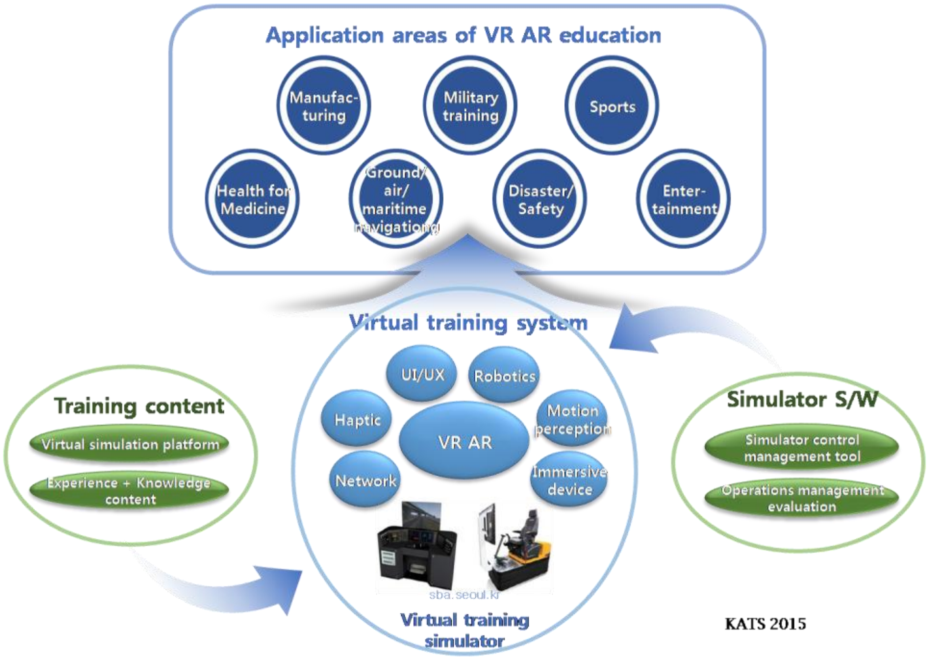


Figure 3.8 Virtual education and training systems framework

4 Information modeling architecture for virtual education and training

Virtual education and training systems can be developed with systems integration technologies. Figure 4.1 illustrates the basic information modeling architecture for the systems. The four horizontal layers at the left represent the hierarchy of technologies necessary for systems integration in all areas. Starting with the bottom layer, ICT fundamental technologies should be the basis for all areas of systems integration. The next layers represent the need for ICT information modeling, ICT information exchange, and ICT information interaction and interface when developing the systems. The four vertical layers at the right represent the integration of technologies. ICT visualization includes all technologies at the horizontal layers, as does ICT visualization processing. Systems integration includes all technologies at the vertical layers, as well as an additional area to be integrated with ICT. Therefore, virtual education and training systems need all the technologies at the horizontal and vertical layers. ISO/IEC JTC 1/SC 24 is focusing on standards development in ICT visualization and its data processing areas. SC 29 is focusing on standards development in ICT data transmission, processing, and encoding/decoding. SC 36 is focusing on learning, education, and training and their data processing areas.

In Figure 4.2, the horizontal layers correspond to visual technology, visual information modeling, visual information exchange, and visual information interaction from the technical point of view for ISO/IEC JTC 1/SC 24 and SC29. For SC36, the layers correspond to education technology, education information modeling, education information exchange, and education information interaction. When developing systems integration applications, real world information, including various types of sensors, should be included. In this case, another layer should be added to the horizontal layers. In Figure 4.3, the top most layer represents information processing in relation to real word sensors and the facilities necessary for systems integration applications. In order to process real world information at this layer, VR, AR, and MR technologies should be used. The two rightmost columns represent these technologies. Amongst the many applications in systems integration areas, virtual education and training systems are typical examples. These reside in the systems integration area.

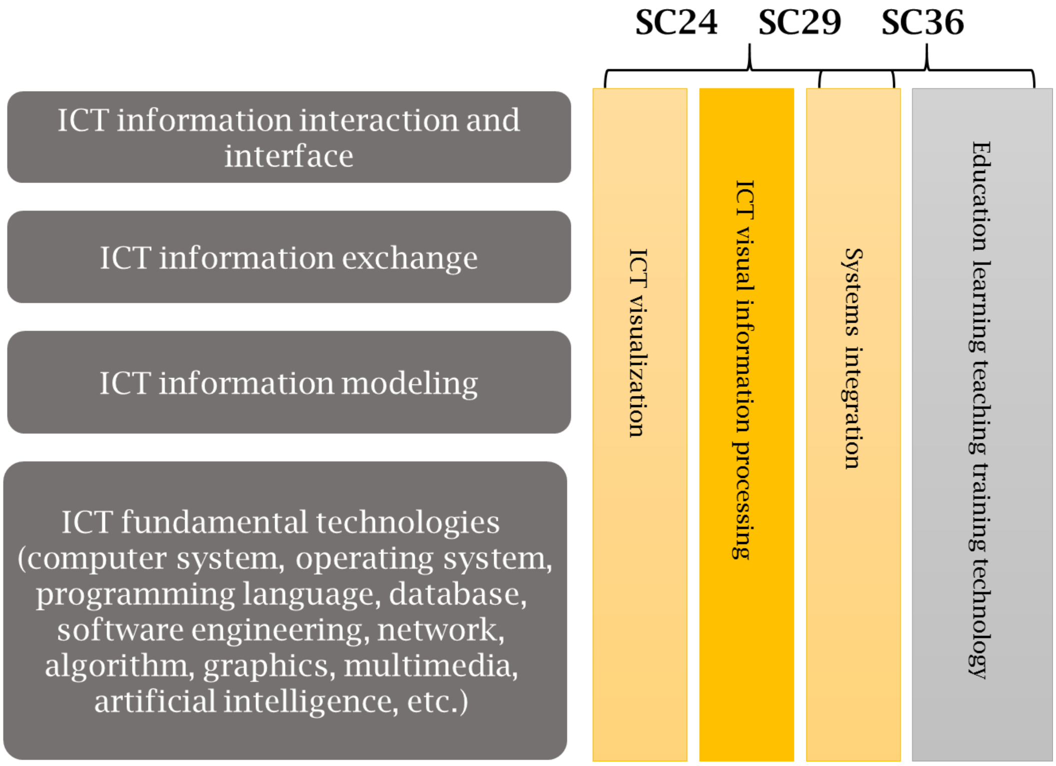


Figure 4.1 Basic architecture for developing ICT integration systems

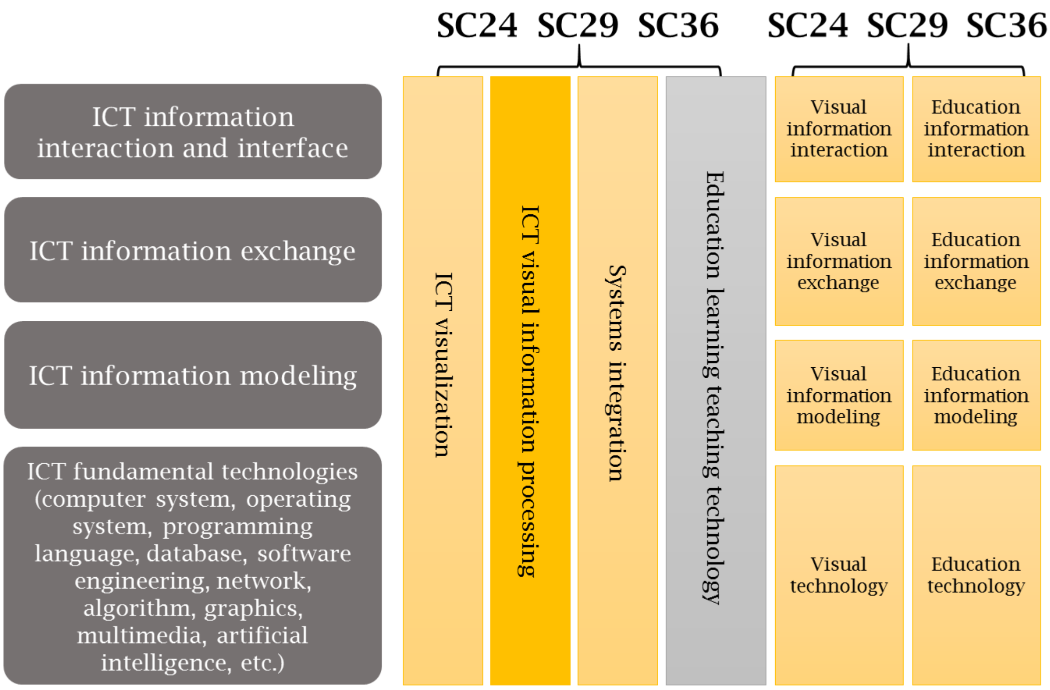


Figure 4.2 Architecture for integrating ICT visual information and education

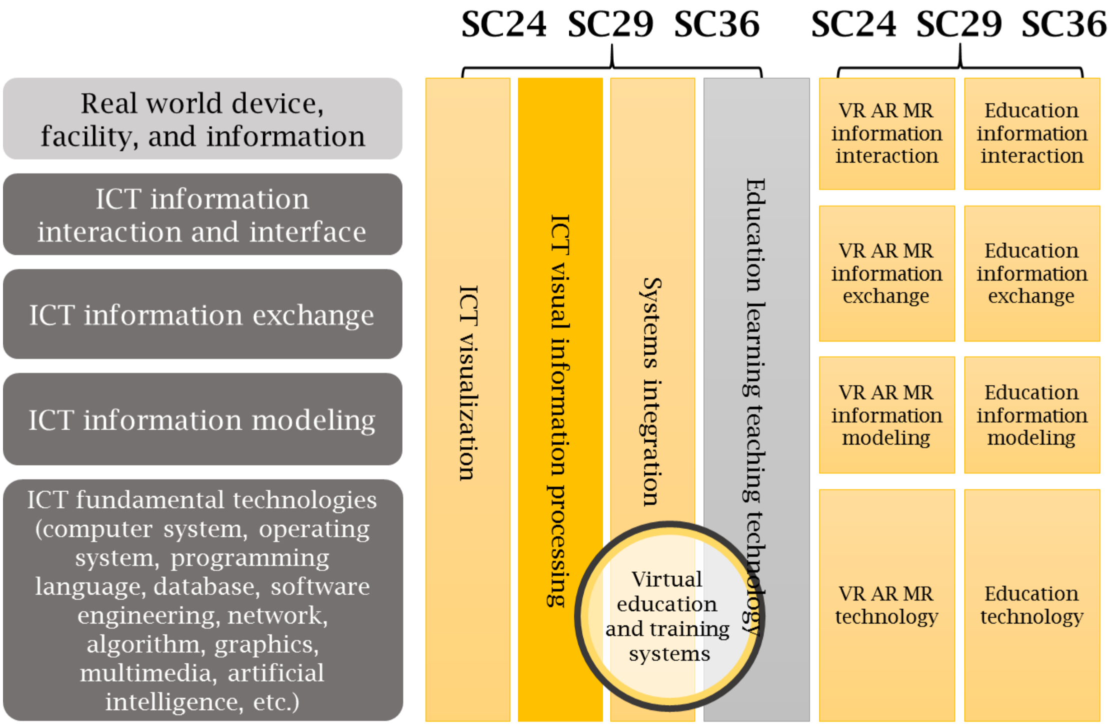


Figure 4.3 Virtual education and training systems and systems integration

Regarding the development of virtual education and training systems, Figure 4.4 shows the role of each working group in JTC 1/SC 24, Figure 4.5 shows the role of each working group in JTC 1/SC 29, and Figure 4.6 shows the role of each working group in JTC 1/SC 36.

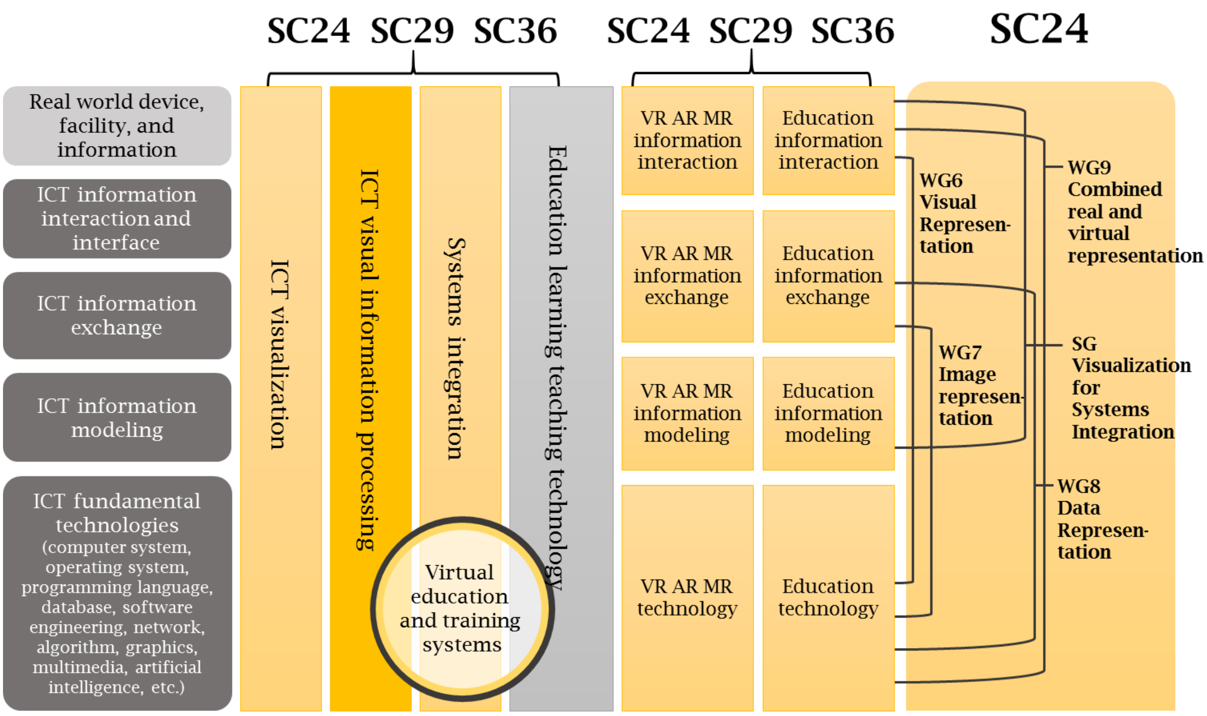


Figure 4.4 SC24 working and study groups for virtual education and training systems

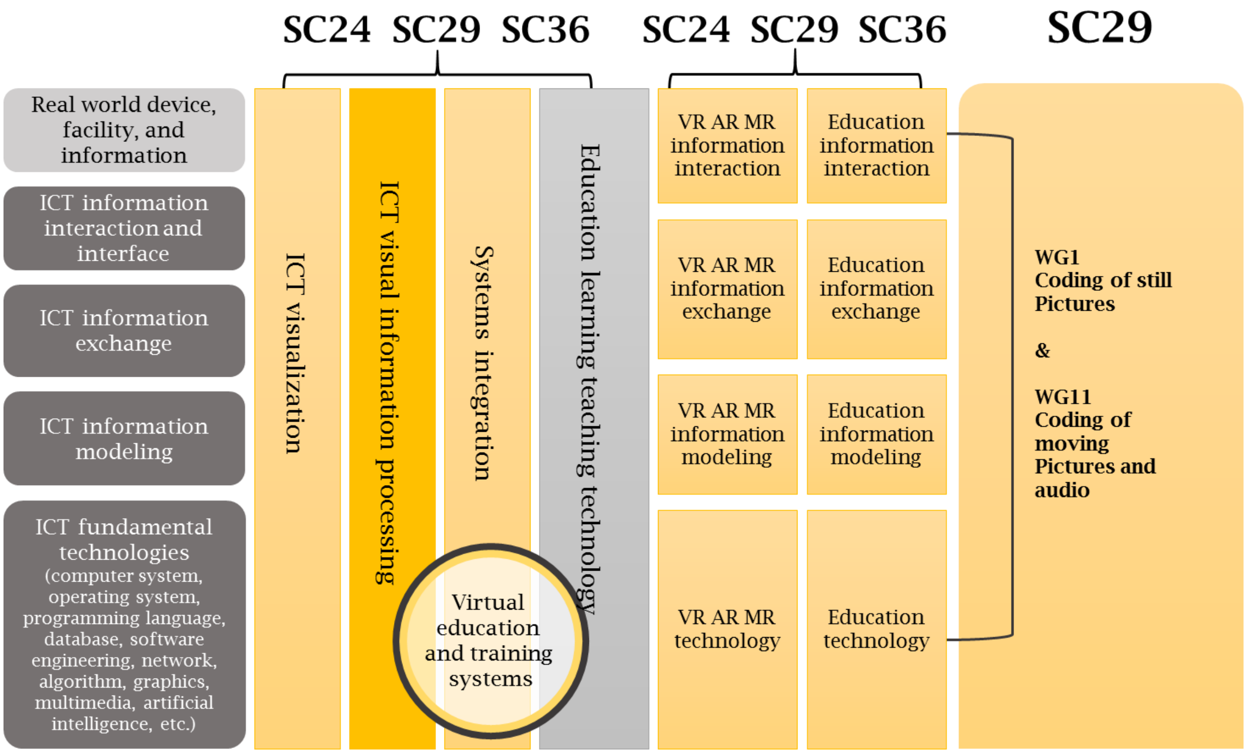


Figure 4.5 SC29 working groups for virtual education and training systems

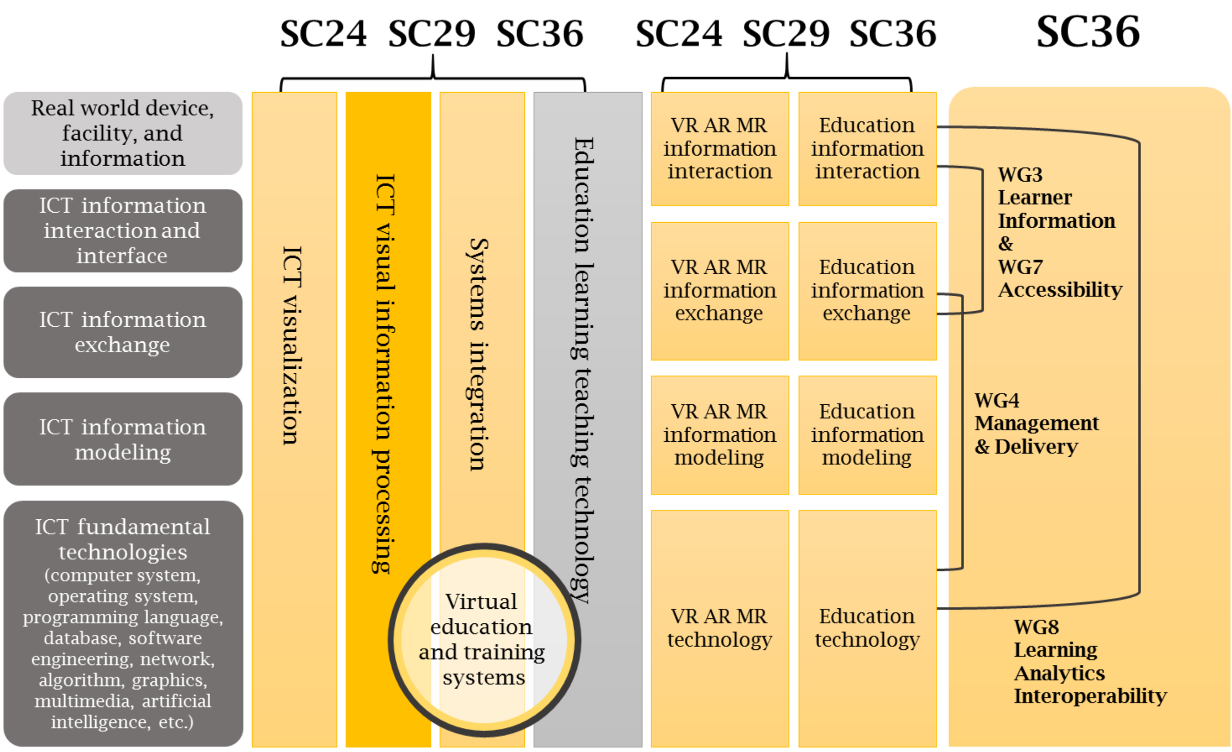


Figure 4.6 SC36 working groups for virtual education and training systems

5 Standard technology for virtual education and training systems

Standard technologies should be integrated when developing virtual education and training systems. This clause describes the classification of the necessary standards and which subcommittees are related to the development of the standards. Details of the standards will be discussed in the next clause. Standard technology should be provided in the following functional areas:

- Virtual environment representation for virtual education and training
- Virtual simulation interface with virtual environments
- Virtual simulation with real world environments and sensors
- Information transmission, exchange, and interaction
- Education and training information description and manipulation

First, virtual environments should be represented with a standardized data model and interface so that they can be generated for common use and exchanged between applications. VR and AR scenes should be created and managed for virtual education and training. Education and training information can be represented in the virtual environments. Second, an interface should be defined for simulating education and training information in virtual environments. The interface controls the virtual environment so as to represent the change in the scene. Third, real world information from sensors should be represented in virtual environments. In order to represent sensor information, it should be able to be imported, represented and simulated according to learning and teaching procedures. ISO/IEC JTC 1/SC 24 standards can be used for providing the above three functionalities. VR and AR information for education and training should be able to be transmitted across heterogeneous computing environments in a seamless manner. The information should be able to be exchanged and interacted with by learners and teachers. ISO/IEC JTC 1/SC 29 standards can be used for transmission of VR AR data. Lastly, knowledge databases for education and training should be able to be created and manipulated in accordance with learning, education and teaching methods in virtual environments. ISO/IEC JTC 1/SC 36 standards provide education information processing methods that can be integrated into virtual education and training systems. Table 5.1 provides the classification of standards necessary for developing the systems and the related functions and functional types of VR and AR.

Table 5.1 Classification of standards necessary for virtual education and training systems

Necessary standards	Required functions	VR AR functional type
Virtual environment representation	• Representation methods of 3D virtual environments for virtual education • Application interfaces for virtual education environments • Virtual world information file format	VR AR representation information modeling
Virtual simulation interface	• Simulating algorithms depending on types of education and training • Simulating interface for education and training information	VR AR simulation in virtual worlds
Virtual simulation with real worlds	• Real world simulation in virtual worlds using real world information • Interfaces for importing and exporting real world information	VR AR interface with real worlds
Information transmission	• Multimedia compression and transmission • Compressed and secured information transmission for education and training	VR AR transmission
Education and	• Description and manipulation of education and	Education information

training information	training information • Managing education and training • Learning, education, and training methods	modeling using VR AR

6 Standards based functional components for virtual education and training systems

JTC 1 standards and work items can be applied when developing virtual education and training systems based on VR and AR technologies. For each required function item discussed in the previous clause, standards and work items in JTC 1 can be used in the following subclauses.

6.1 Virtual environment representation

Virtual environments for education and training should provide a standardized virtual 3D space that can define and exchange education and training objects in heterogeneous computing environments. The following ISO/IEC JTC 1/SC 24 standards can be used for representing and generating virtual environments in which learning and training are displayed as 3D scenes:

- ISO/IEC 14772 VRML (Virtual Reality Modeling Language)
- ISO/IEC 14772-2 VRML97 Functionality and External Authoring Interface
- ISO/IEC 19775-1 V3.3 X3D (Extensible 3D)

VRML and X3D are standards used for generating and exchanging 3D scenes in various computing environments, including the Internet[3]. They are implemented as 3D file formats that include all graphical information necessary for representing and interacting with a scene in a virtual environment. VRML describes fundamental 3D graphics scenes and interaction functions[4]. Figure 6.1 shows the architecture of VRML systems when implementing VR applications. X3D is a 3D graphics file format using XML and has many functions that are enhancements over VRML[5]. X3D establishes a world coordinate space for all objects, and composes a set of 2D, 3D, and multimedia objects. Figure 6.2 shows the architecture of X3D systems when generating VR worlds. X3D VRML and X3D can be used for developing Web-based or general 3D applications with virtual environments.

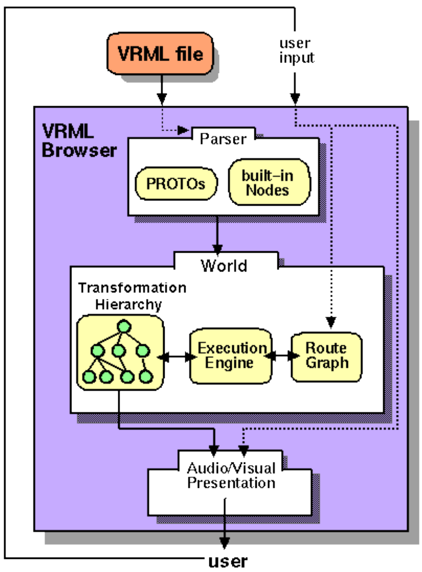


Figure 6.1 Architecture of Virtual Reality Modeling Language (VRML)

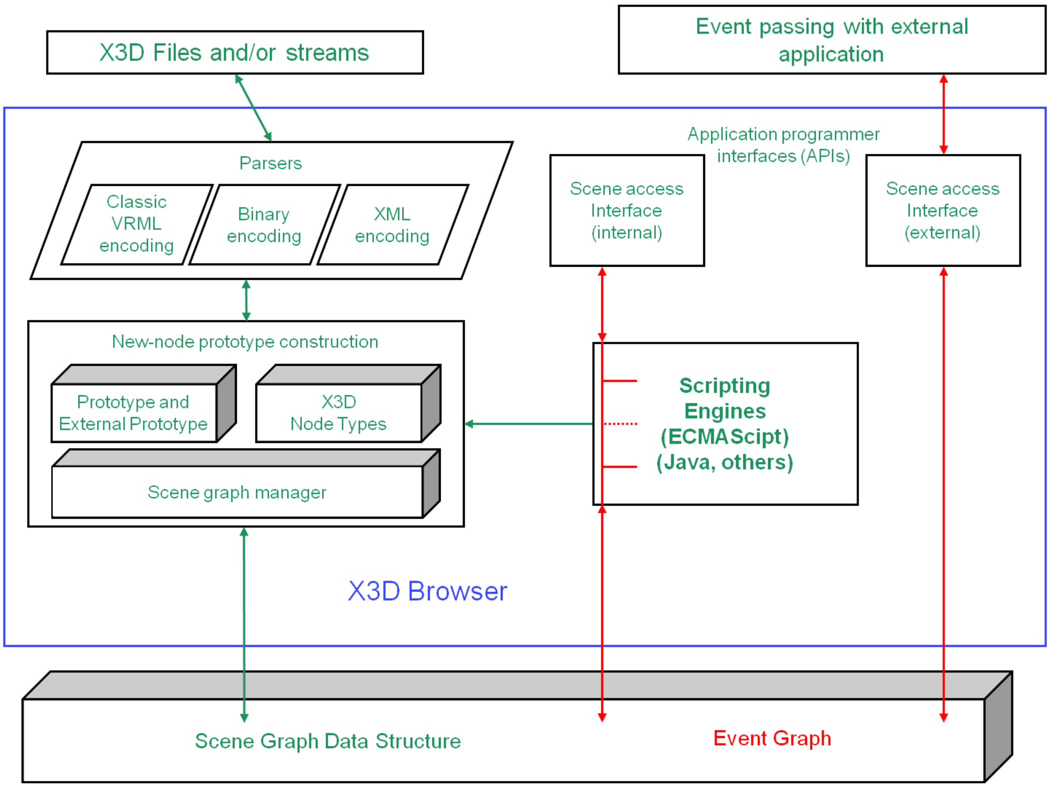


Figure 6.2 Architecture of Extensible 3D (X3D)

The following standards provide 3D environmental data representation that can be used for generating and defining a semantic real world in a virtual environment. All semantic information for representing the real world can be defined using the standards. An environmental data dictionary can be provided in relation to geographical information in virtual environments. Figure 6.3 shows the concepts of SEDRIS (Synthetic Environment Data Representation and Interchange Specification).

- ISO/IEC 18023-1 SEDRIS Part 1: Functional Specification
- ISO/IEC 18025 EDCS (Environmental Data Coding Specification)
- ISO/IEC 18026 SRM (Spatial Reference Model)

SEDRIS is a standard for representing environmental data and for the interchange of environmental data sets[6]. It offers a data representation model, augmented with its environmental data coding specification (EDCS)[7] and spatial reference model (SRM)[8], so that one set of environmental data can be articulated clearly, while also using the same representation model to understand another set of data unambiguously. Therefore, the data representation aspect of SEDRIS is about capturing and communicating meaning and semantics.

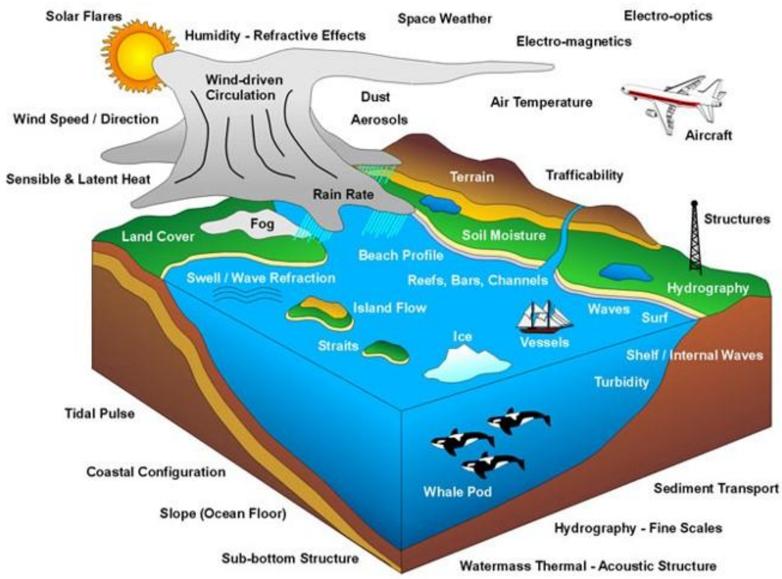


Figure 6.3 Synthetic Environment Data Representation and Interchange Specification (SEDRIS)

3D humanoid representation is also necessary when generating virtual environments. Humanoid models should be able to be defined and managed within virtual environments for education and training. The following standards define 3D humanoid models and an architecture that can be used for education and training:

- ISO/IEC 19774 Humanoid Animation (H-Anim)
- ISO/IEC FDIS 19774-1 Humanoid Animation(H-Anim) Part 1: Architecture
- ISO/IEC FDIS 19774-2 Humanoid Animation(H-Anim) Part 2: Motion data animation

H-Anim specifies the structure and manipulation of H-Anim figures[9]. H-Anim figures are articulated 3D representations that depict animated characters. While H-Anim figures are intended to represent human-like characters, they are based on a general concept that is not limited to the same number of limbs, head, and other body parts that are typical of human beings. A single H-Anim figure is called a humanoid. H-Anim Part 1 is an enhanced version of ISO/IEC 19774 which specifies the architecture of humanoids based on medical terms[10]. H-Anim Part 2 specifies basic concepts of humanoid animation and an overall procedure for defining humanoid animation using an H-Anim model and motion data[11]. Motion parameters necessary for generating humanoid animation are defined. Humanoid animation data is organized using these parameters and the geometric data of a humanoid model. Figure 6.4 represents the joints and segments of a human figure with LOA (Level of Articulation) 3.

Figure 6.5 shows the procedure of generating H-Anim based humanoid animation. It specifies three types of humanoid animation: keyframe animation, algorithm animation, and motion data animation. These can be used for representing humanoid figures in virtual environments. Table 6.1 provides a summary of standards that can be used for representing 3D virtual environments for virtual education and training.

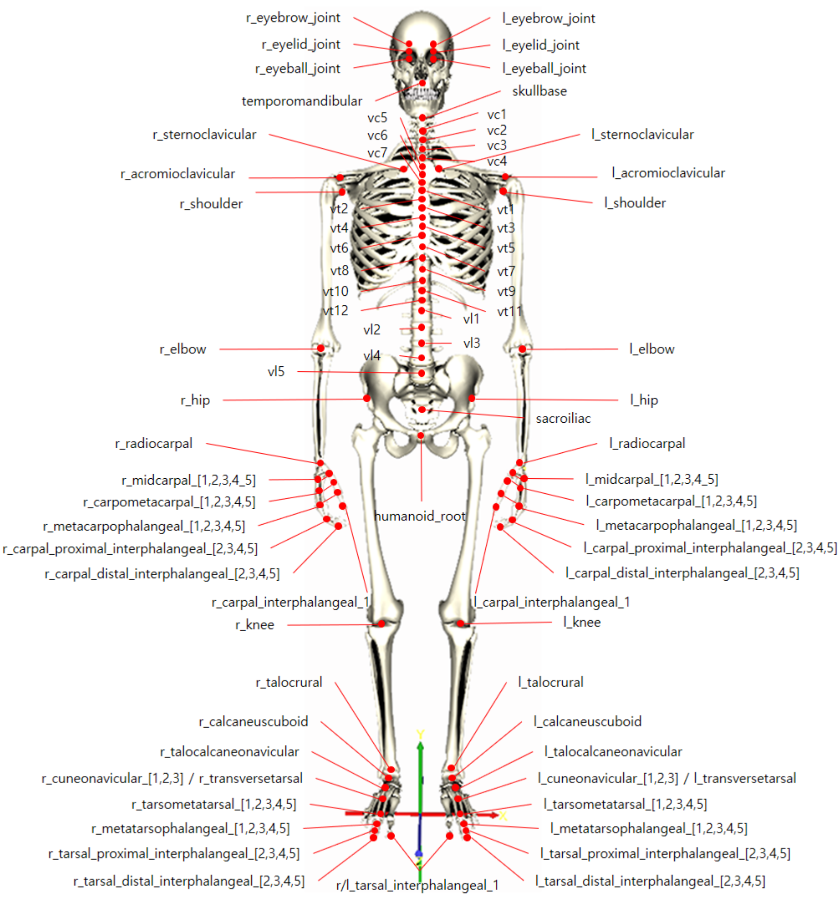


Figure 6.4 Level of Articulation (LOA) 3 of Humanoid Animation (H-Anim)

Table 6.1 Standards for virtual environments representation

Functions necessary for virtual environments	Advantages for education and training	Standards that can be used
3D virtual environments representation	• 3D environments modeling and rendering • 3D environments animation and simulation • 3D virtual object representation	VRML (ISO/IEC 14772) X3D (ISO/IEC 19775-1)
3D data exchange format	• 3D modeling and animation data format	VRML (ISO/IEC 14772) X3D (ISO/IEC 19775-1)
Environment data representation	• 3D environment data representation (space, atmosphere, terrain, and ocean) • Real world environment simulation	SEDRIS DRM (ISO/IEC 18023-1)
Environment data coding specification	• Classification (naming, labelling, identification) of environmental objects • Semantic environment representation	EDCS (ISO/IEC 18025)
Spatial reference model for environments	• Description of geometrical properties such as position, direction and distance	SRM (ISO/IEC 18026)

	• Interoperability of spatial data representation by spatial reference frames	
Humanoid modeling and animation data format	• Human figure and avatar representation • Human animation representation • Human modeling and animation data exchange	H-Anim (ISO/IEC 19774)

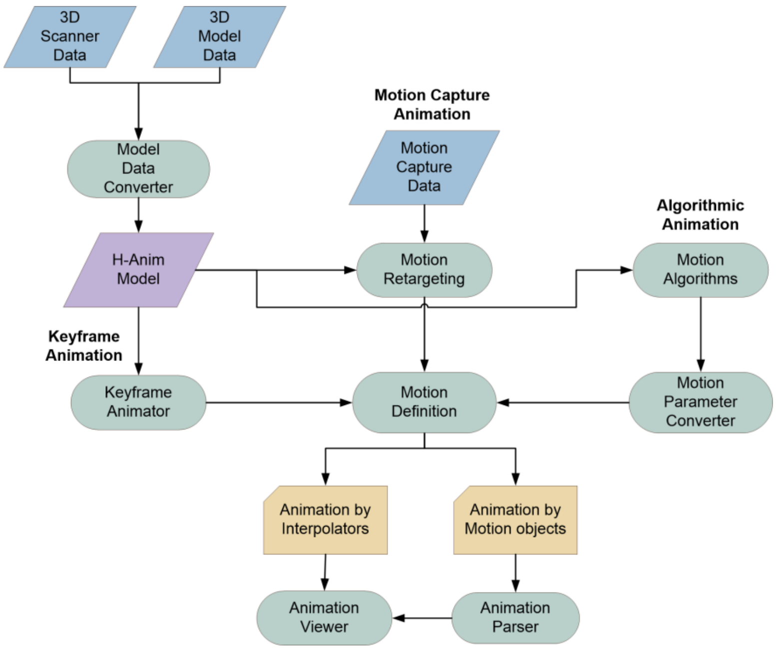


Figure 6.5 Procedure of motion data animation

6.2 Virtual simulation interface with virtual environments

In order to educate and train in virtual environments, user interfaces for manipulating and interacting with virtual environments should be provided. There are two levels of interfaces, categorized as application programming interfaces and graphical user interfaces. The former provides developers with interfaces so that they can generate various applications with standard data and functions, while the latter is a graphical interactive facility that can be used to manipulate objects in virtual environments directly. It can be used when visualizing, simulating, and managing virtual environments without the need for programming. The former can be provided by the following standards.

- ISO/IEC 19775-2 V3.3 X3D Scene Authoring Interface (SAI)
- ISO/IEC 19777-1 V3.0 X3D Language Bindings: ECMAScript (JavaScript)
- ISO/IEC 19777-2 V3.0 X3D Language Bindings: Java
- ISO/IEC 18024-4 SEDRIS Language Bindings -Part 4: C
- ISO/IEC 18041-4 EDCS Language Bindings - Part 4: C

- ISO/IEC 18042-4 SRM Language Bindings - Part 4: C

X3D SAI provides a language-neutral representation of all actions that can be performed by an external application across this interface[12]. Bindings to specific languages are defined in ISO/IEC 19777[13-14]. The SAI forms a common interface that can be used for manipulating browsers and a scene graph from either an external application or from inside the scene graph itself. X3D virtual environments for education and training can be simulated and manipulated by using X3D SAI. X3D language bindings provide a set of implementation-independent objects. These objects represent the possible interactions with the X3D scene through the SAI. Access to the information stored in a SEDRIS transmittal is through an API. The abstract specification for this API is defined in ISO/IEC 18023-1[6]. A part of ISO/IEC 18024 defines the binding of the abstract specification to a particular programming language[15]. Environmental data coding specification and spatial reference model can also be manipulated with a specific programming language binding[16-17].

The latter graphical user interfaces for end users, are simulation tools for education and training. All simulation parameters should be able to be represented and controlled by the tools so that users have direct control. Standard interfaces can be obtained by developing them using the SAI and language bindings specifications.

In order to facilitate interactions between users and between systems in education and training, effective transmittal formats should be supported for virtual environments. VRML and X3D have functions to provide users with the capability to interact with other users and systems in common virtual environments through networks and Web-based applications. In addition, several transmittal formats can also be used, as follows:

- ISO/IEC 19776-1 V3.3 X3D Encoding: XML
- ISO/IEC 19776-2 V3.0 X3D Encoding: Classic VRML
- ISO/IEC 19776-3 V3.3 X3D Encoding: Compressed Binary
- ISO/IEC 18023-2 SEDRIS Part 2: Abstract Transmittal Format
- ISO/IEC 18023-3 SEDRIS Part 3: Transmittal Format Binary Encoding

XML is used for self-validating X3D encoding. This X3D encoding provides a Web-compatible format that maximizes interoperability with other Web languages[18]. X3D can also be encoded by classic VRML. The syntax of X3D in terms of VRML encoding is specified in ISO/IEC 19776-2[19]. The semantics of X3D is defined in ISO/IEC 19775-1. X3D compressed binary format is specified in ISO/IEC 19776-3[20]. This X3D encoding provides a compact transmission format that minimizes delivery size and maximizes parsing speed while following the precepts of XML. SEDRIS abstract transmittal format provides a platform independent interchange mechanism for SEDRIS data for virtual environments[21]. The abstract transmittal format is a conceptual file format that defines the organization of persistent SEDRIS data. A transmittal encoded using the techniques defined in this part of ISO/IEC 18023 consists of a set of files that collectively are termed an STF-encoded transmittal. STF is a file format that defines the syntax of binary-encoded SEDRIS data[22].

Table 6.2 provides a summary of standards that can be used for accessing, manipulating, and interacting with 3D virtual scenes.

Table 6.2 Standards for manipulating and interacting with 3D virtual objects and environments

Functions necessary for simulation and interaction with virtual environments	Advantages for education and training	Standards that can be used
3D virtual environments	• 3D virtual scene access and	X3D Scene Authoring Interface

authoring interface	manipulation • Application programming interface	(ISO/IEC 19775-2)
3D virtual environments programming interface	• Programming language binding for virtual objects and environments • Interfaces for data structure and functions	X3D language binding: ECMAScript (ISO/IEC 19777-1) X3D language binding: Java (ISO/IEC 19777-2)
3D environment data model programming interface	• Programming language binding for semantic environment data model • User interfaces using programming language to access 3D scenes	SEDRIS language binding (ISO/IEC 18024-4) EDCS language binding (ISO/IEC 18041-4) SRM language binding (ISO/IEC 18042-4)
Web compatible format and binary format for 3D data	• Interoperability with other Web languages • 3D data encoding and binary format for exchange • Transmittal format for virtual environments data	X3D encoding: XML (ISO/IEC 19776-1) X3D encoding: Compressed binary (ISO/IEC 19776-3) SEDRIS Abstract transmittal format (ISO/IEC 18023-2) SEDRIS Transmittal format binary encoding (ISO/IEC 18023-3)

6.3 Virtual simulation with real world environments and sensors

Virtual simulation with real world information including sensors should be able to be represented in virtual environments. In addition, standardized interfaces with real word information should be provided. In order to represent and manage the functions of sensors in virtual environments, sensor information should be processed as functional items necessary for virtual education and training systems. Because there are many types of sensors, and because they have different data, an abstract data format that can be used for the sensors should be provided. Sensor information should be able to be simulated visually and interactively in virtual environments. Interfaces for managing and controlling sensors for learning and teaching should be provided. Some functions can be obtained by using the MAR work items in progress. With this work on MAR representation sensor information can be simulated in virtual environments.

Standardized MAR representation can be obtained with the following standards developed in JTC 1/SC 24:

- ISO/IEC 18039 Mixed and Augmented Reality (MAR) Reference Model
- ISO/IEC FDIS 18038 Sensor Representation in Mixed and Augmented Reality
- ISO/IEC 18040 Live Actor and Entity Representation in Mixed and Augmented Reality

The MAR reference model has an architecture with the following functions: processing the content as specified and expressed in the MAR scene, including additional media content provided in media assets; processing the user input(s); processing the context provided by the sensors capturing real world information; managing the presentation of the final result (aural, visual, haptic, and commands to additional actuators); and managing communication with additional services (Figure 6.6)[23]. Sensor Representation in MAR specifies how to represent physical sensors in 3D virtual environments (Figure 6.7). A scene graph and a system architecture with sensors are defined for organizing virtual environments with sensors[24]. Interaction and interfaces to real and virtual worlds for sensors are described. Live Actor and Entity Representation in MAR specifies system functions for representing real actor video images in a MAR scene[25]. A live actor in a MAR scene can be captured from the physical world, then represented in a 3D virtual world, and can interact with cameras, objects, and AR content in the 3D virtual world according to an input of sensing information (Figure 6.8).

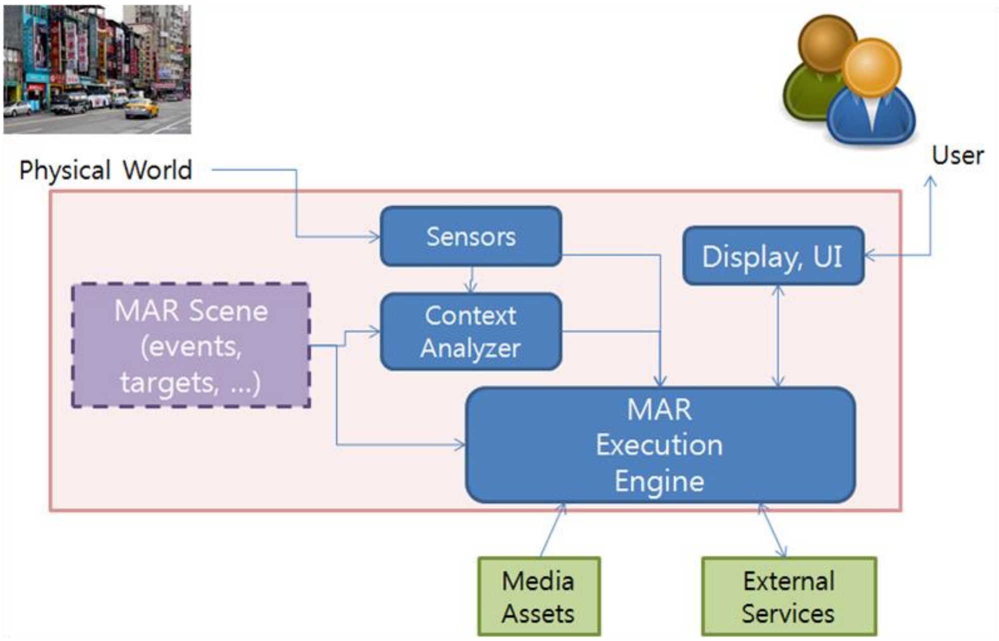


Figure 6.6 MAR reference model

Figure 6.7 Sensor representation in MAR

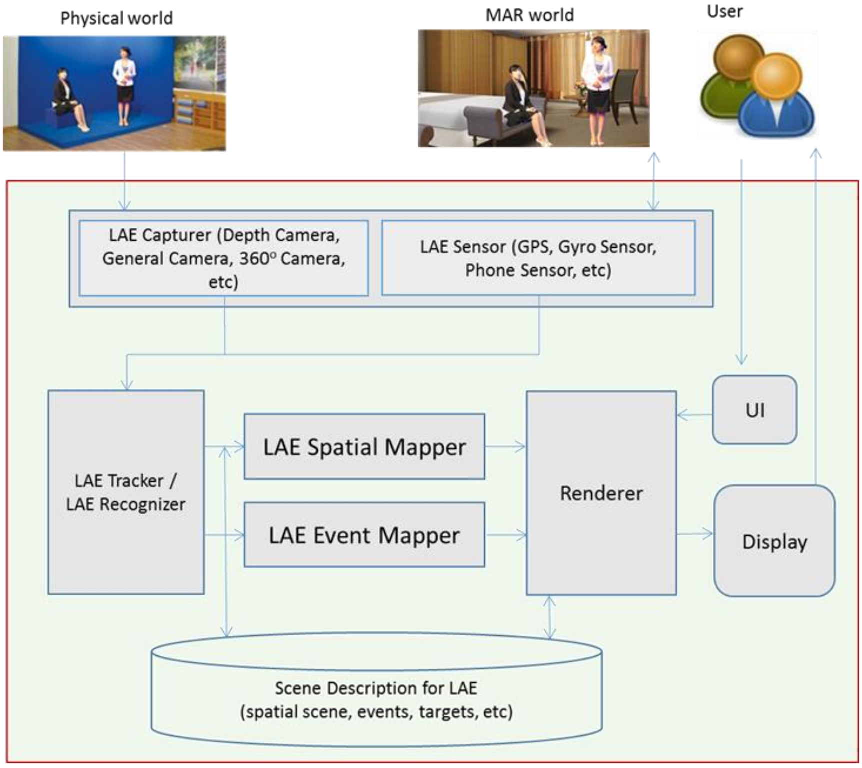


Figure 6.8 Live actor and entity representation in MAR

Table 6.3 provides a summary of standards that can be used for representing real world information in virtual environments.

Table 6.3 Standards for representing and simulating real world information in MAR

Functions necessary for real world information	Advantages for education and training	Standards that can be used
MAR object representation	• A reference model for representing real and virtual objects • Real world information representation	MAR reference model (ISO/IEC 18039)
Sensor information representation in virtual environments	• Sensor representation in 3D virtual environments • Sensor simulation in 3D virtual environments	Sensor representation in MAR (ISO/IEC 18038)
Representation of human figure motion in virtual environments	• Representation of human video information in 3D virtual environments	Live actor and entity representation in MAR (ISO/IEC 18040)

6.4 Information transmission, exchange, and interaction

In order to achieve adequate performance for virtual education and training systems, all information generated during education and training should be able to be transmitted across heterogeneous computing environments and systems using standardized methods and compressed media formats. The following standards can be used when transmitting and exchanging education and training information:

- ISO/IEC 10918 Digital compression and coding of continuous-tone still images (JPEG)

- ISO/IEC 15444-1 JPEG 2000 image coding system: Core coding system
- ISO/IEC 19566-1 JPEG Systems – Part 1: Packaging of information using codestreams and file formats
- ISO/IEC 19566-6 JPEG Systems – Part 6: JPEG 360
- ISO/IEC CD 21794-1 Plenoptic image coding system (JPEG PLENO) – Part 1 Framework
- ISO/IEC CD 21794-2 Plenoptic image coding systems (JPEG PLENO) – Part 2 Lightfield

JPEG specifies an image coding technology and incorporates many options for encoding photographic images. It provides lossy compression for digital images[26]. JPEG 2000 is an image coding system that uses state-of-the-art compression techniques based on wavelength technology and offers an extremely high level of scalability and accessibility[27]. JPEG 2000 can be used with portable digital cameras all the way to advanced pre-press, medical imaging, geospatial and other applications. JPEG systems define an overall framework for the system layer structure of the JPEG standards to ensure interoperability and functionality[28]. JPEG systems further intend to specify system layer extensions that support interactivity protocols, High Dynamic Range (HDR) tools, privacy and security, metadata, 360 degree images, augmented reality, and 3D. JPEG 360 defines a method to represent 360 degree images and to add supplementary metadata and images[29]. JPEG Pleno aims to provide a standard framework for representing new imaging modalities such as texture-plus-depth, light field, point cloud, and holographic imaging. Such imaging should be understood as light representations inspired by the plenoptic function, regardless of which model captured or created all or part of the content[30]. JPEG Pleno standard tools will be designed together to consider their synergies and dependencies for the whole to be effectively greater than the sum of its parts. To fully exploit this holistic approach, JPEG Pleno is not just a set of efficient coding tools addressing compression efficiency. It is a representation framework understood as a fully integrated system for providing advanced functionality support for image manipulation, metadata, random access and interaction, and various file formats. In addition, it should offer privacy protection, ownership rights, and security.

When transmitting multimedia files that contain integrated audio, video, and graphics data that can be used for VR and AR applications, latency should be considered. The following standards can be used for efficient transmission.

- ISO/IEC 14496-11 Scene Description and Application Engine (BIFS: BInary Format for Scenes)
- ISO/IEC 14496-12 ISO Base Media File Format
- ISO/IEC 14496-16 Animation Framework eXtension (AFX)
- ISO/IEC 14496-20 Lightweight Application Scene Representation
- ISO/IEC 14496-25 3D Graphics Compression Model

BIFS is a format that can be used for representing and transmitting multimedia scenes and their application engine[31]. ISO Base Media File Format specifies a file format that can be used for transmitting multimedia data[32]. AFX is a set of compression formats for 3D graphics objects[33]. Lightweight Application Scene Representation specifies an XML-based scene description and interaction format[34]. 3D Graphics Compression Model specifies a model for compressing 3D graphics data[35].

MAR information in a VR and AR based education and training system should be able to be transmitted and exchanged through networks in a seamless way despite the large and composite data transfer. The following standards can be used to transmit the MAR information.

- ISO/IEC 23000-13 Augmented Reality Application Format
- ISO/IEC 23000-18 Media Linking Application Format
- ISO/IEC 23005-1 Media context and control – Part 1: Architecture
- ISO/IEC 23008-2 High Efficiency Video Coding
- ISO/IEC 23008-3 3D Audio

Augmented Reality Application Format (MPEG-A) is a format to enable consumption of 2D/3D multimedia content (Figure 6.9)[36]. MPEG-A is a collection of a subset of the ISO/IEC 14496-11 (MPEG-4 part 11) Scene Description and Application Engine standard. Media Linking Application Format specifies a format that connects a specific spatiotemporal portion of source content with a specific spatiotemporal portion of destination content[37]. Media context and control specifies the architecture of MPEG-V, use cases of information adaptation from virtual world to real world, information adaptation from real world to virtual world, and information exchange between virtual worlds[38]. High Efficiency Video Coding specifies a video format with a compression capability twice that of AVC[39]. This standard includes the metadata for 360 video. 3D Audio specifies 3D audio signals and flexible rendering for the playback of 3D audio in a wide variety of listening scenarios(HEVC)[40].

As the performance of various display and capturing devices advances, immersive media is enabled through improvements in multimedia data processing and transmission capabilities. Immersive media standards have been developed focusing on data format, metadata, and data container, as follows:

- ISO/IEC 23090-1 Immersive Media Architectures
- ISO/IEC 23090-2 Omnidirectional Media Format
- ISO/IEC 23090-3 Versatile Video Coding
- ISO/IEC 23090-4 Immersive Audio
- ISO/IEC 23090-5 Point Cloud Coding
- ISO/IEC 23090-6 Immersive Media Metrics
- ISO/IEC 23090-7 Immersive Media Metadata
- ISO/IEC 23090-9 Geometry-based Point Cloud Compression
- ISO/IEC 23090-10 Carriage of Point Cloud Data

Immersive Media Architectures specifies architectures and nomenclature for immersive media. They define the elements of an immersive experience in the production and in its consumption. The Technical Report will document minimum quality requirements as well as quality objectives for an uncompressed immersive media experience as a whole[41]. Omnidirectional Media Format (Figure 6.10) specifies an omnidirectional media format for coding, delivery, and rendering of omnidirectional media including video, images, audio, and timed text[42]. The user's viewing perspective is from the centre of a sphere looking towards the inside surface of the sphere. Immersive video specifies coded representation of versatile video[43]. Immersive Audio specifies coded representation of immersive audio[44]. Point Cloud Coding specifies coded representation of point cloud data[45]. Immersive Media Metrics specifies a metric for immersive media[46]. Immersive Media Metadata specifies metadata for immersive media[47]. Geometry-based Point Cloud Compression specifies lossless and lossy coding of time-varying 3D point clouds with associated attributes such as color and material properties. This technology is appropriate especially for sparse point clouds[48]. Carriage of Point Cloud Data is the file format for coded representation of point cloud data[49].

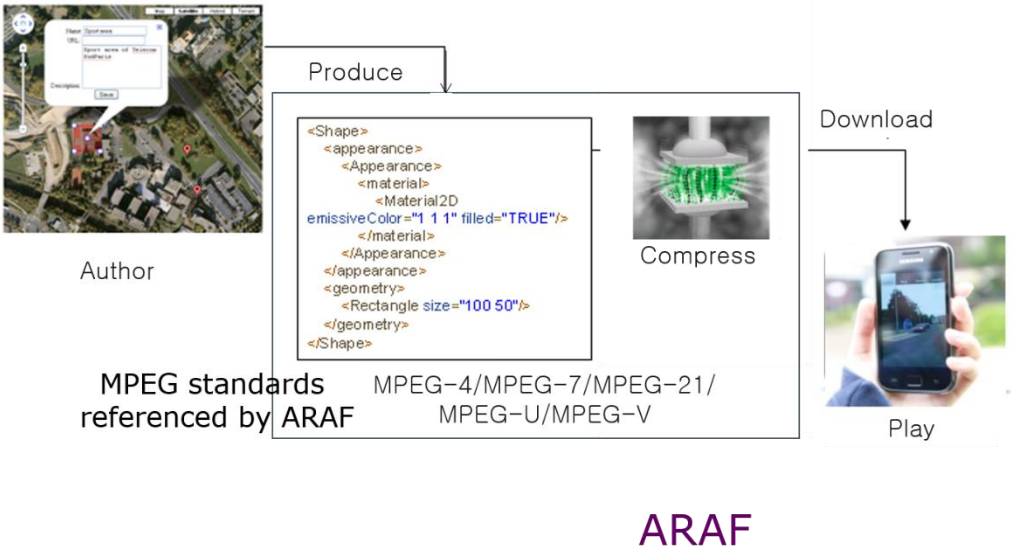
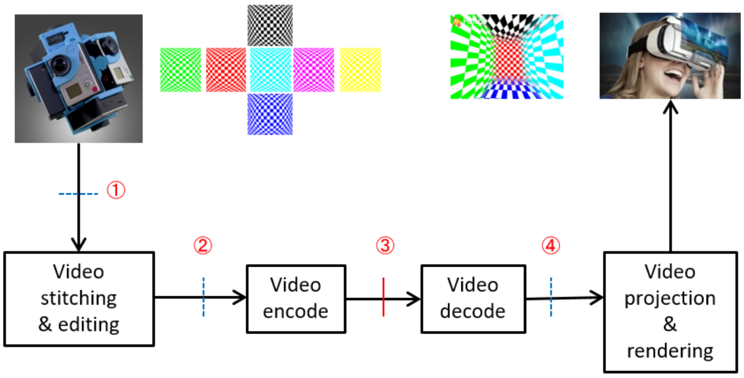


Figure 6.9 ISO/IEC 23000-13 Augmented Reality Application Format (ARAF)

Table 6.4 shows a summary of SC 29 standards that can be used for transmitting virtual education and training information.

Table 6.4 Standards for VR AR data transmission

Functions necessary for transmission	Advantages for education and training	Standards that can be used
Image and video data compression	• Fast transmission • Realtime interaction • Resource saving	JPEG (ISO/IEC 15444) MPEG (ISO/IEC 23001)
Multimedia file format for transmission	• Compressed file format	MPEG-A (ISO/IEC 23000-9) MPEG-4 (ISO/IEC 14496)
Video and virtual world integration	• Media information adaptation and control between video and virtual worlds	MPEG-V (ISO/IEC 23005)
360 video transmission	• Highly compressed transmission of 360 VR data • Supports all commonly used progressive scan picture formats with arbitrary size	HEVC (ISO/IEC 23008-8)
3D audio	• Automatically adapt audio program material to the target number of loudspeakers	3D Audio (ISO/IEC 23008-3)
Coded representation of immersive media	• A compressed data container for AR and VR data • Supports compressed and uncompressed cinematic open source formats	MPEG-I (ISO/IEC 23090)



1	Multiple Videos, Capture Metadata	
2	Single Video, Projection Metadata, Interactivity Data	
3	Storage & Delivery Format	OMAF
4	Single Video, Projection Metadata, Interactivity Data	

Figure 6.10 ISO/IEC 23090-2 Omnidirectional Media Format (OMAF)

6.5 Education and training information description and manipulation

Learning, education, and training (LET) methods and procedures should be able to be simulated in virtual environments. It is necessary that LET information is defined in a standardized format when organizing knowledge databases. LET should also provide users with interfaces that can manage and control LET interaction in virtual environments.

Figure 6.11 illustrates the LET components necessary for VR based education and training. VR files can be generated within an architecture that provides users with education and training capabilities in virtual environments. A school's VR LET environment can be obtained from learning and teaching methods and procedures in virtual environments. Interfaces between the VR device, the VR engine, the school's VR LET environment, and VR controllers should be provided so that LET information can be controlled and managed in a seamless way throughout all the components.

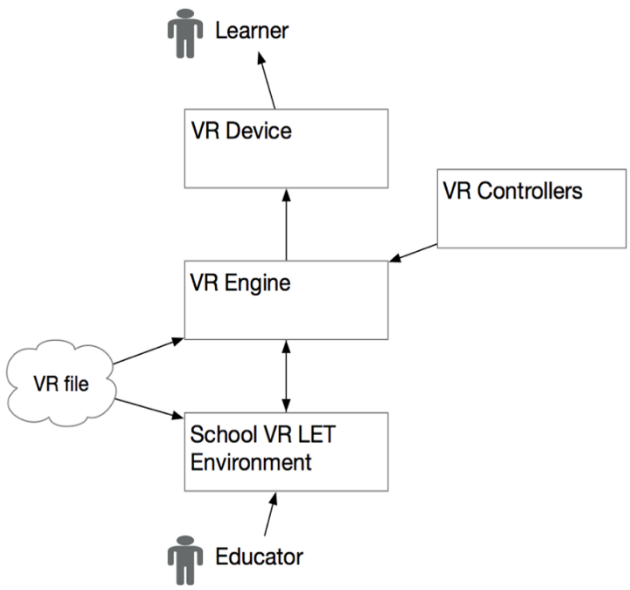


Figure 6.11 LET components for VR based education and training

Information about LET methods, and knowledge bases, should be able to be uniquely defined and accessed in heterogeneous computing environments. Interfaces to access the information should be provided. VR based learning and teaching can be obtained and functionally achieved using the following standards:

- ISO/IEC 19788 Metadata for learning resources
- ISO/IEC 20748 Learning analytics interoperability
- ISO/IEC 20821 Learning environment components for automated contents adaptation
- ISO/IEC 22602 Competency models expressed in MLR

ISO/IEC 19788 specifies metadata elements and their attributes for the description of learning resources[50]. It includes rules governing the identification of data elements and specification of their attributes. ISO/IEC 20748 specifies a reference model that identifies the diverse IT system requirements for learning analytics interoperability[51]. The reference model identifies relevant terminology, user requirements, workflow, and a reference architecture for learning analytics.

ISO/IEC 20821 describes a learning environment profile to support the establishment of mobile learning environments and defines a standard set of terms used to express device information and learning environments for mobile learning[52]. It contains two methods. One is the profile expression method that displays device information language and includes definitions of schema and vocabulary. The other is the profile grouping method that displays terminal information language and includes a group profile example.

- ISO/IEC 24751-1 Individualized adaptability and accessibility in e-Learning, education and training
- ISO/IEC 18121 Virtual experiment framework
- ISO/IEC 19778 Collaborative technology -- Collaborative workplace

ISO/IEC 24751 is intended to meet the needs of learners with disabilities and for teachers working with these learners in an educational context[53]. It provides a common framework to describe and specify learner needs and preferences on the one hand, and the corresponding description of the digital learning resources on the other hand, so that individual learner preferences and needs can be matched with the appropriate user interface tools and digital learning resources. ISO/IEC 18121 defines a framework for IT standards and specifications for virtual experiments supporting IT-enhanced learning, education, and training (ITLET)[54]. It is based on implementations of standards and specifications that are used to support virtual experiment, development, evaluation, and management that rely on ITLET. It promotes the appropriate design and application of virtual experiments. It also provides a sample architecture of a virtual experiment system framework that can be used to support further development of virtual experiments. ISO/IEC 19778 specifies a table-based approach for defining data models[55]. It is used for specifying the collaborative workplace data model for describing data elements and their relationships. It provides for the portability and reuse of data in integrated form and allows data model instantiations to be interchanged, stored, retrieved, reused, or analyzed by a variety of systems.

- ISO/IEC 23988 Information technology -- A code of practice for the use of information technology (IT) in the delivery of assessments

ISO/IEC 23988 gives recommendations on the use of information technology to deliver assessments to candidates and to record and score their responses[56]. Its scope is defined in terms of three dimensions: the type of assessment to which it applies, the stage of the assessment “lifecycle” to which it applies, and the IT aspect on which it is focused.

Table 6.5 provides a summary of SC 36 standards that can be used for defining, manipulating and managing virtual education and training information.

Table 6.5 Functions and standards for managing virtual education and training information

Functions necessary for education information description	Advantages for education and training	Standards that can be used
Methods of managing learning resources	• Provision for describing methods for learning resources and data elements • Management of learning resource databases	Metadata for learning resources (ISO/IEC 19788)
A reference model for ICT education information systems	• Reference to develop an ICT system for learning analytics • Provision of methods for managing human resources	Learning analytics interoperability (ISO/IEC 20748)
A user interface tool for digital learning resources	• Provision of a common framework for learner needs and preferences • Provision of a tool for learners with disabilities	Individualized adaptability and accessibility in learning, education and training (ISO/IEC 24751)
Virtual experiments	• Provision of a framework for virtual experiments based on ITLET	Virtual experiment framework (ISO/IEC 18121)
Collaborative workplace data model	• Provision of the definition of data models for collaborative workplaces	Collaborative workplace (ISO/IEC 19778)
Assessment for validity and reliability	• Provision of security and fairness of IT-delivered assessments	A code of practice for the use of IT in the delivery of assessments (ISO/IEC 23988)

7 Framework components for implementing virtual education and training systems

Virtual education and training requires that all necessary information is able to be represented and manipulated interactively in a virtual environment. Information will be managed and integrated with a MAR scene graph for the virtual environment. Functional components for implementing virtual education and training systems can be organized as in Figure 7.1. Virtual education and training systems consist of three subsystems that are interconnected in the MAR scene graph. The three subsystems are represented by the three columns in the figure.

The left column represents information simulation processing for education. Education information flows from the top left and is simulated into the scene graph for virtual environments for education and training. Education and training information should first be described with data structures. The data structures include VR and AR objects and simulation objects for education information. The VR and AR objects are represented in the scene, and the simulation objects are commands to simulate the virtual objects for the purpose of education and training. Standards related to the simulation objects and their interfaces with the VR and AR objects are necessary.

The middle column represents VR and AR scene information flow. Visual and sensor objects are processed and sent to the scene graph. A 3D scene graph should integrate with the simulation objects and real world information such as device sensor information. It should be maintained so as to manage and control the simulation objects, VR and AR objects, and sensor objects that are imported from the real world. The VR and AR objects are controlled by the simulation objects and the sensor objects and are represented in the scene graph.

The right column represents external device and application interfaces, allowing any sensor information to be imported to the scene. The sensor information imported from the real world using external applications can be integrated with the VR and AR objects and the simulation objects. The sensor information can change the scene graph when communicating with the VR and AR objects and the simulation objects. Interfaces should be provided between the three types of objects for communication.

The MAR scene graph manager should control education information, 3D visual data with VR and AR, and real world sensor information. Based on the scene graph, education information is simulated with real world information in a 3D virtual environment. The three types of data are managed through the integrated scene graph.

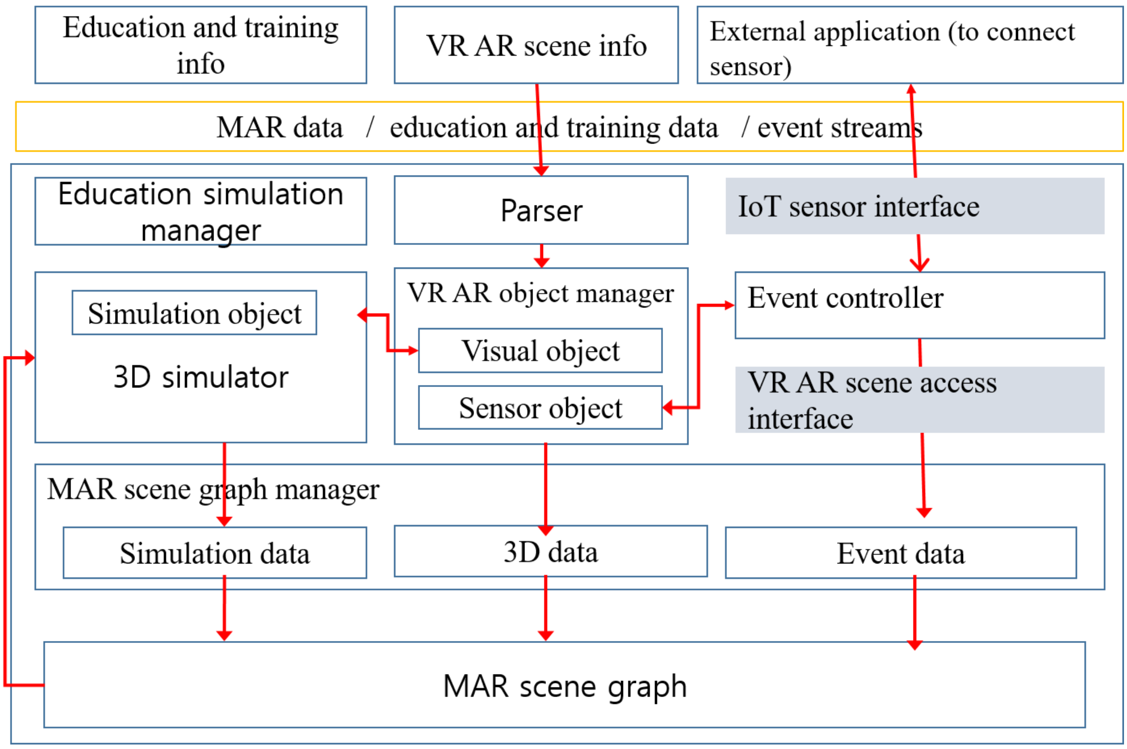


Figure 7.1 Functional components for virtual education and training systems

8 Conclusions and recommendations

In this white paper, several concepts for developing virtual education and training systems using VR and AR were discussed. It is intended to provide industry with guidelines for developing the systems based on standards. These concepts are summarized as follows:

- An information modeling architecture for virtual education and training is defined. It is based on general technologies of ICT integrated systems development. It combines ICT information and real world information in order to implement virtual education and training using VR and AR. Real world information includes sensor information imported from devices.

- Standards based functional system components for virtual education and training using VR and AR were introduced. The components necessary for developing virtual education and training systems are classified by their functionalities and the related standards. The components consist of 3D virtual environments representation, 3D virtual information simulation, 3D real world information simulation, information transmission, and educational information description and manipulation for education and training. Each subsystem can be organized based on standardized technologies.

- System implementation components for virtual education and training using VR and AR were introduced. These organize a system framework for implementing virtual education and training systems. Education and training information is incorporated into and simulated within a virtual environment through a MAR scene graph.

The above systematic approach can provide a standards-based method for developing virtual education and training systems. It can be enhanced with details of the system components and used for developing standards related to VR AR based systems integration. Recommended future work is as follows:

- To enhance industry usage, it is necessary to provide examples of systems design using the systematic approach provided by the guidelines.

- The guidelines for developing virtual education and training systems can be applied and expanded in standards based ICT integrated systems development using VR and AR in other areas.

- Standards for ICT integrated systems using VR and AR can be developed based on the guidelines in this white paper. The following topics can be considered as new work items:

  - A system integration methodology and a framework for virtual education and training systems

  - A system integration methodology and a framework for VR AR based application systems such as 3D human health information systems and wearable information systems

Annex A

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[46] ISO/IEC WD 23090-6 Information technology -- Coded representation of immersive media -- Part 6: Immersive media metrics

[47] ISO/IEC WD 23090-7 Information technolgy -- Coded representation of immersive media -- Part 7: Immersive media metadata

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[49] ISO/IEC WD 23090-10 Information technology -- Coded representation of immersive media -- Part 10: Carriage of point cloud data

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