IEC TR 63308

Edition 1.0 2021-07

TECHNICAL REPORT

Virtual reality equipment and systems – Market, technology and standards requirements

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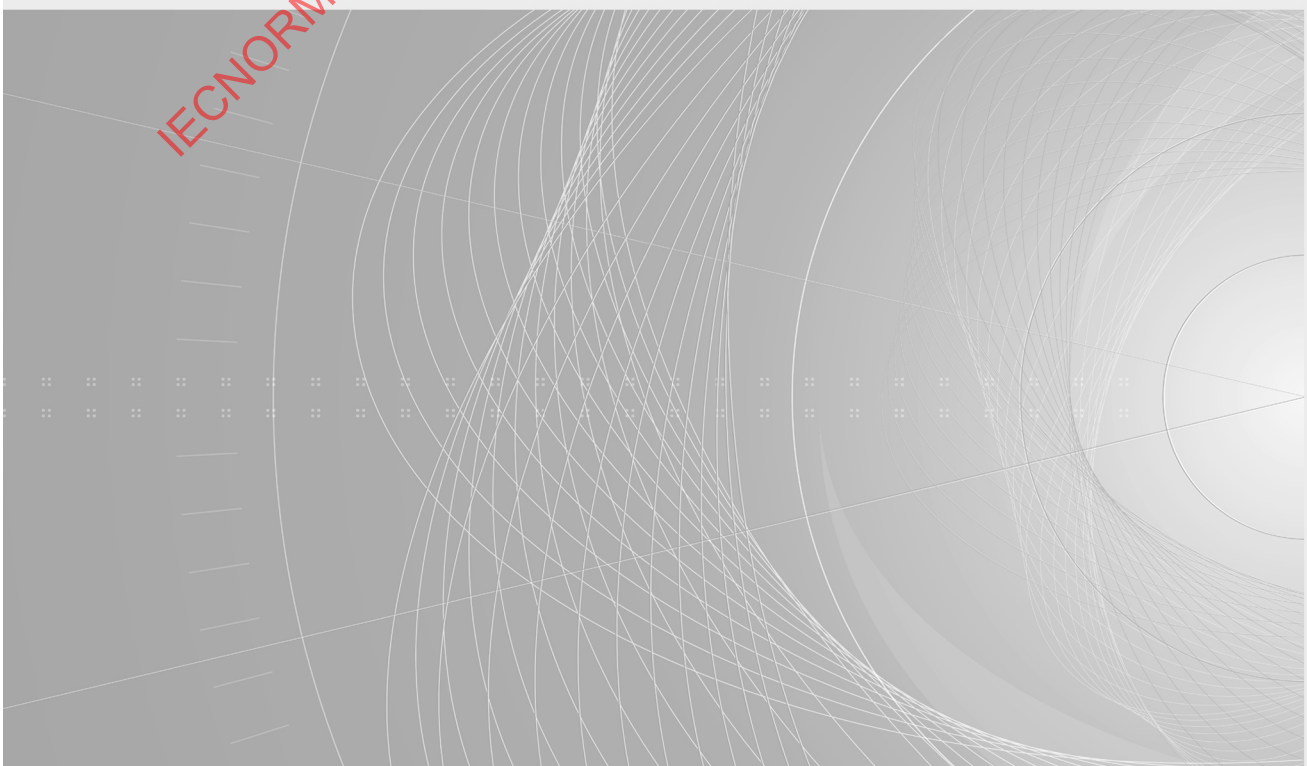

IEC TR 63308:2021-07(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.120; 33.160.99

ISBN 978-2-8322-9945-6

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VIRTUAL REALITY EQUIPMENT AND SYSTEMS – MARKET, TECHNOLOGY AND STANDARDS REQUIREMENTS

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The text of this Technical Report is based on the following documents:

DTR	Report on voting
100/3484/DTR	100/3519/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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INTRODUCTION

Virtual reality (VR) is an interactive computer-generated experience, which allows the user to feel he is in a virtual world where he can interact in and control a virtual environment. The interaction between the user and the virtual world is mainly through auditory and visual stimuli, but it can also include other types of sensory feedback, such as haptic technology.

This Technical Report focuses on VR equipment and systems that are within the scope of TC 100. Firstly, the ecosystem of VR is described, based on a brief view of market trends and analysis of some typical use cases of VR equipment and systems. Then technologies used in VR equipment and systems are listed, in order to introduce a C-P-N-D (Content, Product, Network and Device) based VR system model. Finally, after studying the standardization activities of related standards developing organizations (SDOs), some suggestions are given, including potential standardization topics within the scope of TC 100.

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VIRTUAL REALITY EQUIPMENT AND SYSTEMS – MARKET, TECHNOLOGY AND STANDARDS REQUIREMENTS

1 Scope

This document discusses the market of virtual reality (VR) and the technical domains pertaining to a VR system. This document provides clarity on how existing standards can be used and highlights further requirements for standards within the scope of TC 100.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
head mounted device
HMD
type of computer display device or monitor which is worn on the head or is built in as part of a helmet

3.2
virtual reality
VR
simulation of the physical presence of the user, which is primarily experienced through two of the five senses such as sight and sound, in an environment produced with the help of a computer, enabling the user to interact with this environment

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4 Markets for VR equipment and systems

4.1 Overview of VR markets

In the 1980s, the arrival of stereoscopic '3D' games such as Virtuality and Virtual Boy drew attention to virtual display techniques. Even some films, like Lawnmower Man and Virtuosity, and books, such as Snow Crash, demonstrated the powerful potential of VR. But the technology at the time could not match people's imagination or their expectations; poor image quality, significant latency and high device prices made the first trials of VR products fail in the end.

Since 2014, there has been a second wave of VR technology, and, like most new technologies, VR has had a rocky – but predicable start.

According to the predictions of business intelligence, the market of VR hardware will continue to grow. In 2020, cheaper and high-quality VR headsets rolled out to the market, improving the quality in virtual world experiences. In 2021, the same trend will continue [1][1].

4.2 Customer requirements

Compared with other media, such as film, which intent is also to show a 'real' world to the audience, customers have additional special requirements when it comes to VR experiences. These requirements are similar to other 3D techniques.

– Immersive: Immersive is the basic feature for VR equipment and systems. VR needs to engage both the body and the mind of the viewer: to feel real and to respond as if it was real.

– Believable: VR equipment and systems need to give the feeling of complete belief in the virtual world. This can be achieved through consistent use of logic, physics, and narrative. If the experience is not consistent with user expectations for that virtual world, then the illusion of virtual reality will disappear.

– Interactive: VR equipment and systems can encourage the interaction between the user and the virtual world. As the user moves around, the virtual world needs to move with them. This is a quite unique experience compared with watching a 3D film, the latter cannot provide any interactive experience.

– Response time: Any delay will make the user uncomfortable with the illusion of the virtual world. A powerful processor is required in order to deal with high quality 3D computer graphics. The processor should be powerful enough to provide a believable, interactive, alternative world that changes in real time.

4.3 Typical VR ecosystem

Figure 1 shows a typical VR ecosystem.

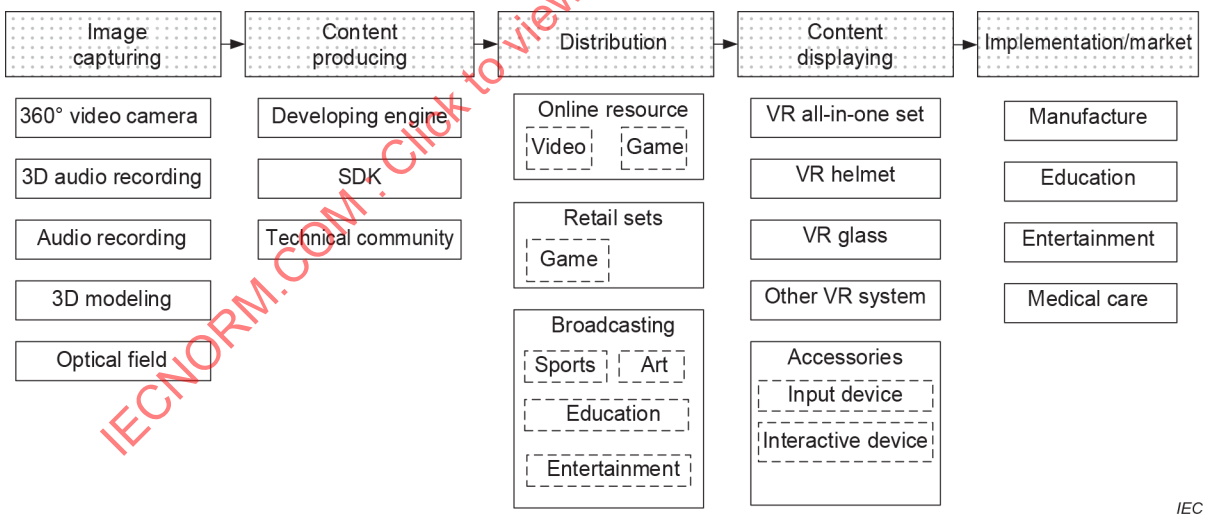

Figure 1 – VR ecosystem

A VR ecosystem normally consists of image capturing, content producing, content distribution and displaying, which explains how users can reach VR contents.

Analysing a VR ecosystem can be helpful to focus on the audio and video equipment and systems, and other related technologies that are within the scope of TC 100, in order to conduct further studies, so that the standardization gap can be filled.

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1 Numbers in square brackets refer to the bibliography.

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5 Typical use cases of VR

In the past 30 years, VR equipment and systems have been used by scientists, doctors, dentists, engineers, architects, archaeologists, and the military, and have been well known to common customers.

In 4.2, the key unique features of VR, which made VR one of the preferred solutions in many specific use cases, are listed.

Table 1 – Typical use cases of VR

Used area	Examples[2]
Design and manufacture	Airbus uses VR programmes to carry out verifications in a virtual space, which can save up to 80 % time compared with traditional methods. Boeing used VR systems in designing the shape and architecture of the B-777. Rolls Royce uses VR technology to observe the detail of engines in its developing steps.
	Neusoft uses VR systems to assemble and debug a whole manufacture system without establishing real plant and equipment. VR systems are used to estimate and calibrate the assembly procedure in Audi vehicles.
	JLIANCO uses VR systems to check the failure of boilers, in order to ensure standard operation and reduce maintenance costs.
Education	IBM and Google developed VR systems which can allow teachers and students to create a virtual world for education, in a vivid and interesting way. VRSCHOOL used VR to set up a VR classroom which is used in physics, astronomy and biology experiments.
	JD used VR systems to train the delivery men for the sorting of goods. NASA used VR systems to train their astronauts on how to perform spacewalking, and what it is like to work with tools in space. The VR systems also simulated a zero-gravity environment in outer space.
Art and entertainment	VR was used to produce a film to introduce Luoyang ancient city and DunHuang MoGao grottoes in the 2019 Smart China Expo. BNC broadcast a TV series called "Halcyon".
	BBC provided VR live broadcasting for the Russian World Cup. CCTV has been providing VR live broadcasting for the Spring Festival party since 2017. www.huajiao.com is a live broadcasting platform, it used VR technology in online live broadcasting to give users more immersive experiences.
	China built a VR theme park in Nanchang, which used VR equipment and systems to provide immersive experiences to users. The Forbidden City in China provided 6 VR tour plans for visitors, including a building introduction, a cultural relic show and ancient history interactive.
	Meiwu365 is a decoration design company in China, it used VR in the design and modification process of their costumes before construction started.
	The new launched VR games such as Batman: Arkham VR and Superhot VR. These are based on games designed for normal controllers, but these versions change so many mechanics and scenarios, that they have essentially become brand new experiences.

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2 This information is given for the convenience of users of this document. This information does not constitute an endorsement by IEC of the products named.

Used area	Examples[2]
Medical care	Taipei Medical University used VR anatomy courses which achieved better results compared with using traditional 2D paper material. Japan Jikei University established a VR operation simulation system, which can give physical feedback.
	Japan Nagasaki Institute uses VR to establish recovery treatment plan for patients, including biological status simulation and movement positioning.
	A drug addiction treatment centre in China used VR for psychotherapy purposes for addicts to help them get rid of the effects of drugs. Applied VR was used by some hospitals to release the pain and anxiety of patients during treatment and operation.
	Shenzhen People Hospital in China used a VR+5G system to perform remote biliopancreatic surgery together with an expert group in Beijing, with a physical distance of over 1 000 km.

Besides the existing use cases listed in Table 1, VR will be used more widely in future, which will bring more attention to this area.

6 Technologies of VR

6.1 Technical domains of VR equipment and systems

VR is an integrated technology that consists of 3D modelling, 3D display, sensor technology, real time graphic processing, etc. The VR equipment and systems are designed to provide an accurate, real and interactive experience to the customer.

The relationship between the different technical domains is shown in Figure 2.

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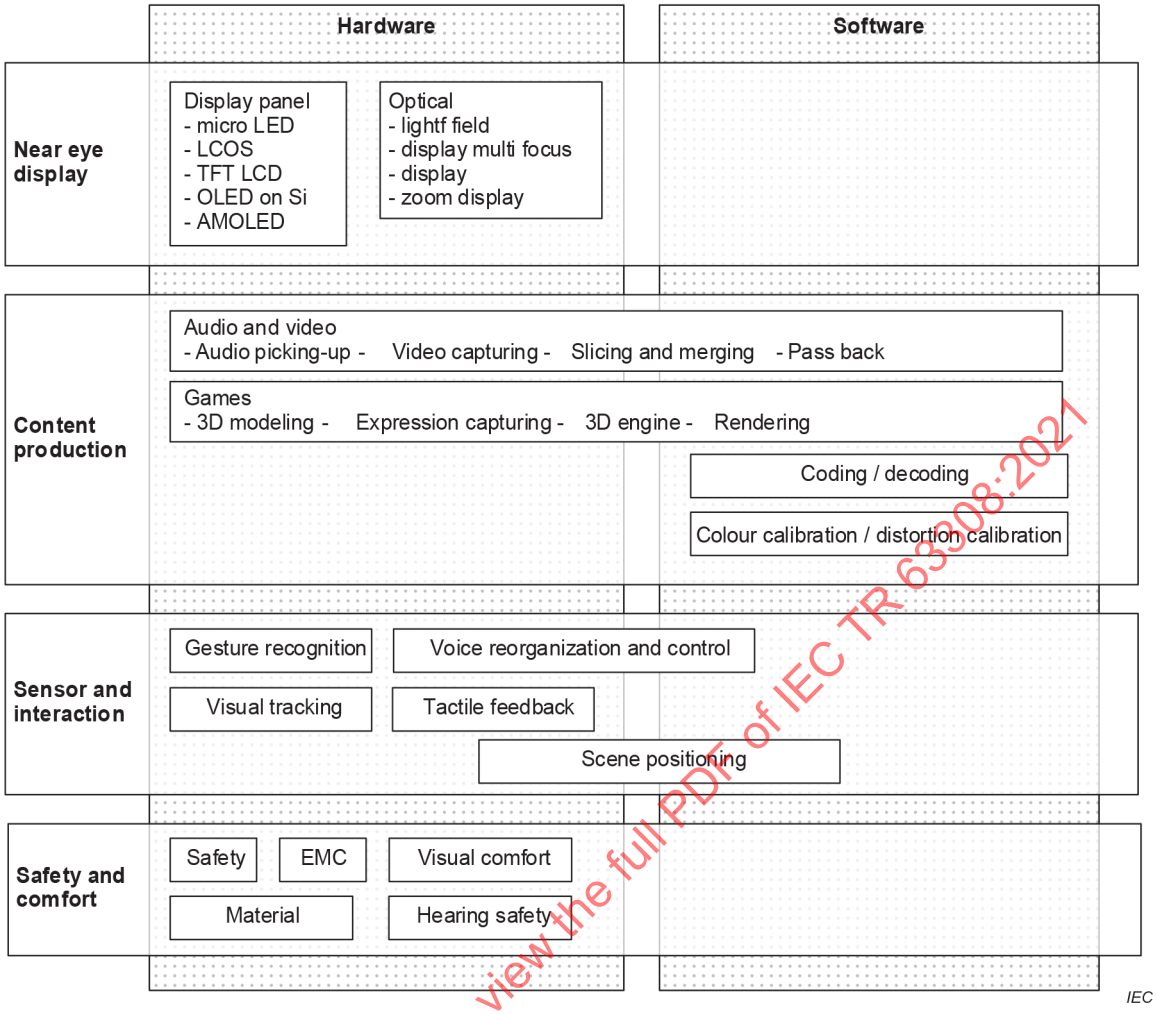

Figure 2 – VR technical domains

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6.2 Factors for display quality of VR equipment and systems

Because VR is intended to be used as a human-machine interface, the display, optical relay and sensors on VR are important for human visual characteristics. Human factors should be considered in this case, as follows:

a) factors affecting detection and recognition with luminance, contrast viewing distance, binocular vision, field of view and colour;

b) geometry factors which are interpupillary distance, pupil size and eye relief;

c) tolerance of aberration such as lateral colour, line distortion and field curvature.

For satisfying human factors, the ideal display for VR should have the following attributes:

d) wide FOV (field of view);

e) small display size with very high resolution;

f) binocular display alignment;

g) high frame rate;

h) adequate luminance and wide colour;

i) low optical distortion;

j) light weight and small size.

One of the immersive factors is a wide FOV. A VR FOV should ideally be the same as that of the human eye, for example 190° to approximately 210° horizontally and 120° to approximately 135° vertically [2], [3].

The eye's ability to detect objects clearly is natural. Because pixels corresponding to an object remain stationary in the video frame for a complete refresh cycle while the eyes move in anticipation of motion, frame frequency of the VR display should be fast enough for the eye's tracking system to catch smooth image movements in pixels corresponding to a moving object.

There is an adaption of human eyes under lighting conditions. Eyes have a very wide dynamic range to see stars at night as well as very bright objects under sunny conditions. So, the contrast range of display would be up to $1:10^9$, because the VR condition is very dark.

One of the functions of the eye is that the human eye can discern a variation of very similar colours. The contrast range and distinguishing the colour difference require a wider colour space than standard red, blue, green (sRGB) and bit rate over 8 bits.

6.3 Visual comfort considerations of VR equipment and systems

6.3.1 General

In order to give more immersive VR experiences to users, VR equipment and systems have to satisfy the requirements of human senses. If there is a mismatch between the human senses and VR equipment and systems, users can experience negative effects such as dizziness and vomiting. Indeed, many users have reported visual discomfort due to the prolonged use of VR equipment and systems. Therefore, visual comfort is one of the important elements for VR equipment and systems.

6.3.2 Binocular disparity

Humans see an object with two eyes, and recognize stereoscopic senses through them. It is one of the ways in which humans perceive depth. This kind of visual perception is called a binocular disparity. The binocular disparity is caused by a pupillary distance or physical distance between two eyes. Since there is pupillary distance, each eye sees a slightly different image of the object. The human brain then combines the two different images and creates a stereo image.

Most of VR equipment and systems have adopted the binocular disparity. In other words, VR equipment and systems send different visual information to each eye, respectively. Then it makes our brain mistaking virtual reality as a real space. Therefore, for giving a VR experience without visual discomfort to users, VR equipment and systems have to be well organized to give appropriate images to which binocular disparity is applied.

6.3.3 Screen door effect

The screen door effect is a visual artifact caused by a display which is adopted in VR equipment and systems. The display consists of numerous pixels, and there are some spaces between each pixel. The space is the area which is not lit, and it could look like a black grid when users use VR equipment and systems. This phenomenon is called the screen door effect.

The screen door effect can occur for all kinds of displays, but it is worse on VR equipment and systems, because our eyes are so close and are looking at the display through magnifying lenses. Therefore, the screen door effect is one of visual discomfort when using VR equipment and systems.

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The screen door effect is less noticeable on high resolution displays where the pixels are arranged more tightly and there is less space between pixels. As the space between pixels reduces, the screen door effect becomes less noticeable and can practically be eliminated. In other words, to reduce or to solve the screen door effect, VR equipment and systems need higher resolution displays. Also, diffusion filter can be adopted in order to make the screen door effect less noticeable.

6.3.4 Motion-to-photon latency

A variety of VR equipment and systems utilizing sensor-based technology have been released. One of these types of sensors detects motion of the head, and it improves the immersive experience for users. However, if there is a mismatch between motion and vision, users can experience motion sickness and dizziness.

The motion-to-photon latency describes the length of time between the user performing a motion and the display showing the appropriate content for that particular motion. Humans are highly perceptive to latency. In VR equipment and systems, up to 20 ms of lag can remain undetected by the user. That is, to prevent the visual discomfort when using VR equipment and systems, the delay time is required to be no more than 20 ms.

6.3.5 Blue light

Viewing conditions of VR equipment and systems are totally different from other types of displays such as TV and monitor. TVs and monitors are used under various ambient conditions. Also, these are large size displays, so users watch TV and monitors from a relatively long distance. On the other hand, VR equipment and systems are used under completely dark conditions, and in very short distances, less than 5 cm from the eyes. Therefore, the optical properties of the display which is adopted for VR equipment and systems directly affect the eye.

Regarding the optical radiation effect on the eyes, most of the ultraviolet that reaches the eye is absorbed by the cornea or the crystalline lens. And the cornea and crystalline lens also block infrared. The net result of light filtering by the ocular media is that the retina is exposed almost exclusively to the visual portion of the solar spectrum. Among these visible portions, blue light can induce photochemical damage. The phototoxicity has been studied and appears to be concentrated in a narrow band of wavelengths centred on 435 nm ± 20 nm. Considering the viewing environment and blue light effect, eyes would be affected by the high intensity of blue light and deep blue under dark conditions during the exposed time when users use VR equipment and systems. Therefore, it is recommended that the display of VR equipment and systems has a long wavelength of blue light.

7 Related work of other SDOs

7.1 IEC TC 110

In 2015, TC 110 set up a working group on eyewear display (EWD) to start standardization work for eyewear display equipment such as VR HMD, VR glasses and other VR products. IEC 63145 (all parts) define the requirements and measurement methods for display devices used for near eye display, which is one of the critical technologies in the area of VR. The existing and future standards are listed in Table 2.

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Table 2 – Existing and future standards of TC 110

No.	Title
IEC 63145-1-1	Eyewear display – Part 1-1: Generic – Introduction
IEC 63145-1-2[3]	Eyewear display – Part 1-2: Generic – Terminology
IEC 63145-10[4]	Eyewear display – Part 10: Specifications
IEC 63145-20-10	Eyewear display – Part 20-10: Fundamental measurement methods – Optical properties
IEC 63145-20-20	Eyewear display – Part 20-20: Fundamental measurement methods – Image quality
IEC 63145-21-20[5]	Eyewear display – Part 21-20: Specific measurement methods for VR image quality – Screen door effect
IEC 63145-30[6]	Eyewear display – Part 30: Durability test methods of eyewear display
IEC 63145-201[7]	Eyewear display – Part 201: Optical components of eyewear display
IEC 63145-40[8]	Eyewear display – Part 40: Measurement methods of specific functions with sensors for eyewear display
IEC 63145-23[9]	Eyewear display – Part 23: Contact lens type
IEC 63145-50[10]	Eyewear display – Part 50: User interaction

7.2 ISO/IEC JTC 1

7.2.1 JTC1

In ISO/IEC JTC 1, SC 24, SC 29 and SC 35 carried out related work in the field of VR.

7.2.2 ISO/IEC JTC 1/SC 24

ISO/IEC JTC 1/SC 24 carried out standardization work for cases where VR is used in education and training systems, which focused on system integration and representation, especially on

– representation of virtual education and training environments;
– interaction with real and virtual training environments;
– simulation of virtual training environments;
– interfaces for managing and controlling virtual training environments.

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3 Under consideration.

4 Under consideration.

5 Under consideration.

6 Under consideration.

7 Under consideration.

8 Under consideration.

9 Under consideration.

10 Under consideration.

The relevant existing standards are listed in Table 3.

Table 3 – Existing standards of ISO/IEC JTC 1/SC 24

No.	Title
ISO/IEC 14772-1:1997	Information technology – Computer graphics and image processing – The Virtual Reality Modeling Language – Part 1: Functional specification and UTF-8 encoding
ISO/IEC 14772-2:2004	Information technology – Computer graphics and image processing – The Virtual Reality Modeling Language (VRML) – Part 2: External authoring interface (EAI)
ISO/IEC 18023-1: 2006	Information technology – SEDRIS – Part 1: Functional specification
ISO/IEC 18023-2: 2006	Information technology – SEDRIS – Part 2: Abstract transmittal format
ISO/IEC 18023-3: 2006	Information technology – SEDRIS – Part 3: Transmittal format binary encoding
ISO/IEC 18024-4: 2006	Information technology – SEDRIS language bindings – Part 4: C
ISO/IEC 18025: 2014	Information technology – Environmental Data Coding Specification (EDCS)
ISO/IEC 18026: 2009	Information technology – Spatial Reference Model (SRM)
ISO/IEC 18041-4: 2007	Information technology – Computer graphics, image processing and environmental data representation – Environmental Data Coding Specification (EDCS) language bindings – Part 4: C
ISO/IEC 18042-4: 2006	Information technology – Computer graphics and image processing – Spatial Reference Model (SRM) language bindings – Part 4: C
ISO/IEC 19774-1:2019	Information technology – Computer graphics, image processing and environmental data representation – Part 1: Humanoid animation (HAnim) architecture
ISO/IEC 19774-2:2019	Information technology – Computer graphics, image processing and environmental data representation – Part 2: Humanoid animation (HAnim) motion data animation
ISO/IEC 19775-1:2013	Information technology – Computer graphics, image processing and environmental data representation – Extensible 3D (X3D) – Part 1: Architecture and base components
ISO/IEC 19775-2:2015	Information technology – Computer graphics, image processing and environmental data representation – Extensible 3D (X3D) – Part 2: Scene access interface (SAI)
ISO/IEC 19776-1:2015	Information technology – Computer graphics, image processing and environmental data representation – Extensible 3D (X3D) encodings – Part 1: Extensible Markup Language (XML) encoding
ISO/IEC 19776-2:2015	Information technology – Computer graphics, image processing and environmental data representation – Extensible 3D (X3D) encodings – Part 2: Classic VRML encoding
ISO/IEC 19776-3:2015	Information technology – Computer graphics, image processing and environmental data representation – Extensible 3D (X3D) encodings – Part 3: Compressed binary encoding
ISO/IEC 19777-1:2006	Information technology – Computer graphics and image processing – Extensible 3D (X3D) language bindings – Part 1: ECMAScript
ISO/IEC 19777-2:2006	Information technology – Computer graphics and image processing – Extensible 3D (X3D) language bindings – Part 2: Java

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7.2.3 ISO/IEC JTC 1/SC 29

SC 29 standards are included in the joint work with SC 24 and SC 36. SC 29has been working on standard technologies and solutions since 1995. Related standards and future standards are listed in Table 4.

Table 4 – Existing and future standards of ISO/IEC JTC 1/SC 29

No.	Title
ISO/IEC 14496-11:2015	Information technology – Coding of audio-visual objects – Part 11: Scene description and application engine
ISO/IEC 14496-12:2020	Information technology – Coding of audio-visual objects – Part 12: ISO base media file format
ISO/IEC 14496-16:2011	Information technology – Coding of audio-visual objects – Part 16: Animation Framework eXtension (AFX)
ISO/IEC 14496-20:2008	Information technology – Coding of audio-visual objects – Part 20: Lightweight Application Scene Representation (LASeR) and Simple Aggregation Format (SAF)
ISO/IEC 14496-25:2011	Information technology – Coding of audio-visual objects – Part 25: 3D Graphics Compression Model
ISO/IEC 23000-13:2017	Information technology – Multimedia application format (MPEG-A) – Part 13: Augmented reality application format
ISO/IEC 23000-18:2018	Information technology – Multimedia application formats (MPEG-A) – Part 18: Media linking application format
ISO/IEC 23000-20[11]	Information technology – Multimedia application formats (MPEG-A) – Part 20: Omnidirectional media application format
ISO/IEC 23008-2:2020	Information technology – High efficiency coding and media delivery in heterogeneous environments – Part 2: High efficiency video coding
ISO/IEC 23008-3:2019	Information technology – High efficiency coding and media delivery in heterogeneous environments – Part 3: 3D audio
ISO/IEC 23090-2:2019	Information technology – Coded representation of immersive media – Part 2: Omnidirectional media format
ISO/IEC 23090-3:2021	Information technology – Coded representation of immersive media – Part 3: Versatile video coding
ISO/IEC 23090-5[12]	Information technology – Coded representation of immersive media – Part 5: Visual volumetric video-based coding (V3C) and video-based point cloud compression (V-PCC)
ISO/IEC 23090-6[13]	Information technology – Coded representation of immersive media – Immersive media metrics
ISO/IEC 23090-7[14]	Information technology – Coded representation of immersive media – Immersive media metadata
ISO/IEC 18039:2019	Information technology – Computer graphics, image processing and environmental data representation – Mixed and augmented reality (MAR) reference model

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7.2.4 ISO/IEC JTC 1/SC 36

JTC-1/SC 36 work in the field of VR environment for education. Related standards are listed in Table 5.

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11 Under consideration.

12 Under consideration.

13 Under consideration.

14 Under consideration.

Table 5 – Existing standards of ISO/IEC JTC 1/SC 36

No.	Title
ISO/IEC 19788 (all parts)	Information technology – Learning, education and training – Metadata for learning resources
ISO/IEC 20748 (all parts)	Information technology for learning, education and training – Learning analytics interoperability
ISO/IEC TR 20821	Information technology – Learning, education and training – Learning environment components for automated contents adaptation
ISO/IEC 22602	Information technology – Learning, education and training – Competency models expressed in MLR
ISO/IEC 24751 (all parts)	Information technology – Individualized adaptability and accessibility in e-learning, education and training
ISO/IEC TR 18121	Information technology – Learning, education and training – Virtual experiment framework
ISO/IEC 19778 (all parts)	Information technology – Learning, education and training – Collaborative technology – Collaborative workplace
ISO/IEC 23988	Information technology – A code of practice for the use of information technology (IT) in the delivery of assessments

In future, JTC-1 will still push the VR related items to move forward by

- preparing guidelines for developing standardized virtual education and training systems;
- refining JTC1 standards and standardization for virtual training and education systems;
- enhancing the architecture for systems integration for virtual education and training systems;
- expanding the concepts of systems integration with education and training to other systems integrations.

7.3 ITU

In 2017, the ITU radio department started a project on advanced immersive audio visual system (AIAV), to carry out research on content production, expected effect and evaluation method of the AIAV system. The report introduced the progress of the related experiments and the standardization of VR. Two Japanese manuscripts introduced the VR/AR program and the progress of the 360 degree VR images in the 8K program. AIAV system parameters are currently being developed for program production and exchange.

A working group within ITU has launched a research on immersive live experience (ILE) system and business. Four projects are now under way, they are H.ILE-SS (Service scenario of immersive live experience), H.ILE-Reqs (Requirements for immersive live experience (ILE) services), H.ILE-FW (Architectural framework for immersive for live experience (ILE) services) and H.ILE-MMT (Service configuration, media transport protocols and signalling information of MMT for Immersive Live Experience (ILE) systems).

8 Potential standardization items in TC 100

8.1 Expected standard framework for VR systems

Based on the analysis of existing VR market and technology trends, the standards that are expected to be developed for VR equipment and systems are shown in Figure 3, the standards are not only those that should be considered by TC 100, but also include those that should be studied by other TCs/SCs.

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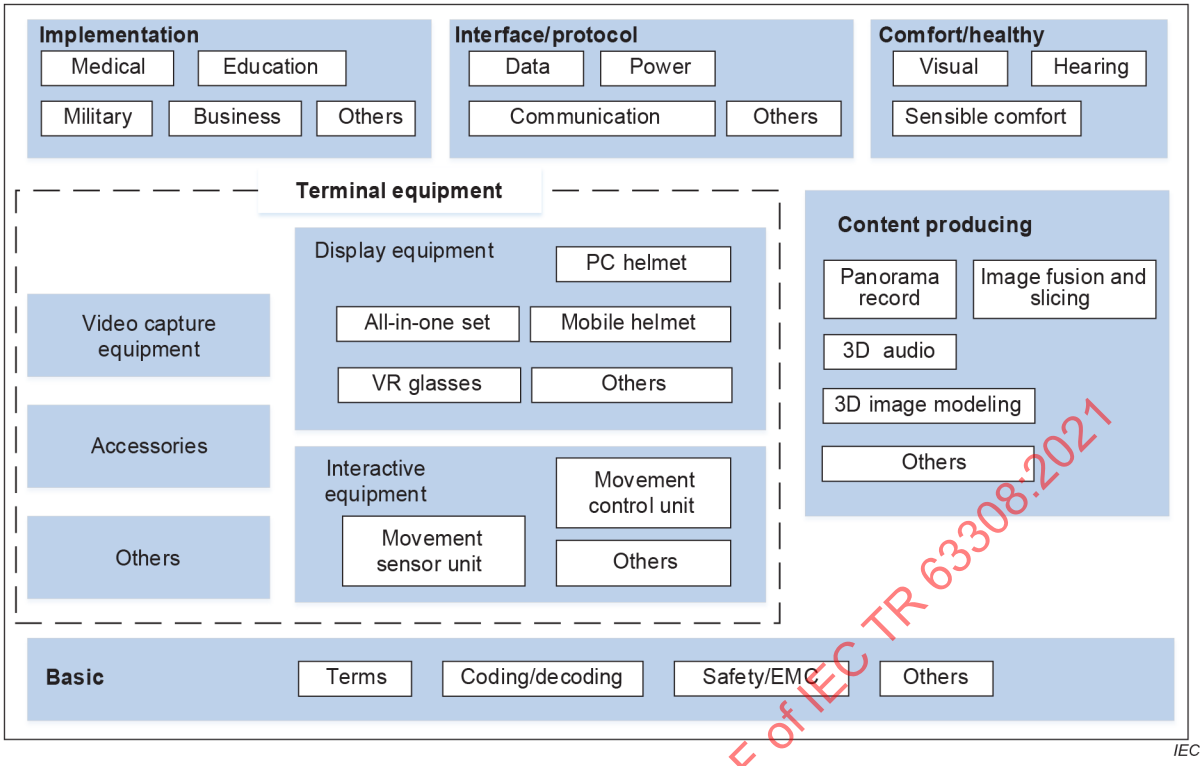

Figure 3 – VR standard framework

Figure 3 shows the VR standard framework, which is derived from the analysis of the VR ecosystem and technology domains.

Terms, standards for coding and decoding, standards for safety and EMC requirements, are all included in the basic section, these standards will be referenced in all other related standards.

As for the content producing section, the standards for panorama record, image fusion and slicing, 3D audio and 3D image modelling are listed.

In the terminal equipment section, all the standards used for display equipment, interactive equipment, video capture equipment and accessories will be included.

In the interface and protocol section, the data interface, power interface, communication protocol will be standardized.

In the safety and EMC section, the safety and EMC requirements for VR equipment and systems will be defined, in order to ensure the safety of users.

The implementation section will include the standards which aim to meet special requirements for unified scenario such as education, military, medical and business.

8.2 Possible new work items

TC 100 set up a study session on VR technology in 2017, and started to analyse potential standard issues in the field of audio, video and multimedia systems and equipment.

In this document, based on analysis of VR market, ecosystem and technical domains, some new work items can include the following:

– performance evaluation;

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