Indian Journal of Science and Technology, Vol 9(25), DOI: 10.17485/ijst/2016/v9i25/97234, July 2016
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Study on the Head Mounted Display (HMD)-Based VR Contents and Producing Method

Jung-Yeob Han

Department of Virtual and Augmented Reality, Namseoul University, Korea; wengee@hanmail.net

Abstract

Background/Objectives: Year 2016 has been presented as the starting year of Virtual Reality (VR). However, there has been little study on VR content production techniques. **Methods /Statistical analysis:** The purpose of this study was to examine various VR content production techniques and present the direction for development of VR contents. For methodology, the study classified production techniques for 15 contents in 3 areas, i.e., 5 contents of 360° life-size shooting, 5 contents based on 3D low polygon, and 5 contents of 360° animation which were differentiated in terms of production techniques and contents among 109 VR contents registered on March 3, 2016 which were on VR platforms provided by Oculus Rift. Furthermore, the study presented production methods applying concerned techniques and their characteristics. **Findings:** The results of this study showed that VR contents could be defined as real-size image, 2 and 3D low-polygon VR contents, and 360° animation, depending on production characteristics. First, 360° life-size shooting technique was suitable for special locations and situations such as performance, movies, etc., but did not enable presentation such as lighting, etc. Furthermore, 360° life-size is shooting required special technology and much time for the latter part works such as stitching, special effects, etc., in connection with production technique. Second, 3D low polygon-based VR contents enabled simulation with excellent sense of presence and immersion based on 0.02 second latency by reducing the number of 3D polygons from 30,000 to 50,000. However, it had the disadvantage of degraded reality of images. Third, 360° animation production technique enabled various presentations and enhanced image quality, but had limitation that it enabled only fragmentary interaction and simulation. Improvements/Applications: Future VR content would need to be developed in such a way that efficiency and synergic effects can be maximized by combining the advantages of various production techniques, depending on the purpose and needs of VR contents, rather than applying single production technique.

Keywords: Contents, HMD, Producing Technique, Virtual Reality, 360°

1. Introduction

1. 1. Background and Purpose of the Study

Greenlight Virtual Reality (VR), a world-renowned business intelligence company, formed 11 major types and 22 elements of the VR industry ecosystem in 2015 for 1,500 companies with the Head Mounted Display (HMD) display, VR hardware, VR production equipment, VR software, VR application, VR research, VR technology and VR service[1]. In the VR device sector, Stephanie Liamas, the director of the Super Data Consumer Research, announced that 56 million VR devices would be distributed this year and the market revenue would mark $5.1 billion (6.1 trillion KRW)[2]. In addition, VR leading companies like Oculus Rift and Gear VR provided free VR platforms to produce various VR contents and form new VR industry ecosystem from the unidirectional VR contents consumption to the prosumer aspect. The domestic VR contents market shows the progress in that Samsung Venture Capital invested to '8i', a New Zealand VR contents producting company last month, decided the investment to Baobab Studio, a US VR animation producer with Comcast and HTC in early this month. Also,

*Author for correspondence

Samsung Electronics Co. Ltd. cooperated with National History Museum to invest to VR contents production to experience ancient oceanic ecosystem[3].

With this viewpoint, it is high time to develop killer contents and activate next generation VR platform assuming that 2016 is the beginning of the VRAR industry[4]. Small and medium Korean companies have attempted various VR contents production but there is no systematic study on the most important factor, VR producing technique. Therefore, the purpose of the study was to investigate VR contents production technique based on the VR platform provided to Oculus Rift and Samsung Galaxy Gear and find out the future direction of VR contents to be predicted in the future.

1.2. Scope and Method of the Study

The scope is limited to VR common platform provided by Oculus Rift and Gear VR. The study selected 15 contents with distinct technique and contents including 5 360° real image contents, 5 3D low-polygon contents and 5 360° animations among 109 VR contents registered to the platform as of March 3, 2016. There has been no systematic study on the VR contents technique. Therefore, the study classified producing technique types based on 15 VR contents selected in the study and proposed the development direction by proposing samples and process with the technique. The technique analysis sheet classified producing technique of VR common platform contents and formed the title, producer, producing technique and production type of contents as shown in the sheet like Table 1.

Table 1. VR Contents production technique analysis sheet

Contents image	Title and producer	Production technique	Genre and feature

2. Theoretical Background of the VR Contents

2.1. Head Mounted Display (HMD) Paradigm

The first Head Mounted Display (HMD) was introduced in 1968 from the research titled "A Head-Mounted Three Dimensional Display" by Professor Ivan Sutherland at Utah University in[5]. Since then, there have been several attempts to provide multi-dimensional images by surrounding eyes of users through two small Cathode-Ray Tubes (CRTs) like the HMD. However, the HMD at that time showed poor user interface and experience application[6]. Particularly, the HMD was too heavy and the device was fixed on the ceiling. Then, after rapid development, the HMD in 1990s was represented by Forte VFX-1 in 1995 and Sony Glasstron in 1997. The former integrated the personal TV, video and portable headset and was equipped with the world-first polymer organic diode micro display [7]. The latter provided two LCD screens, video and earphone to play the game. Then, Sensics piSight, the MD with 6 million pixels was developed with the optical tile multiple display by Larry Brown and Mark Shapiro at Johns Hopkins University in[8]. Recently, DK1 of Oculus Rift which made its debut in 2012 has succeeded the history of HMD[9]. The leader of the HMD companies in 2016 and other leading companies in the industry include Oculus DK2 and Crescent Bay Prototype of the US, Sony HMZ-T3W of Japan and Samsung Galaxy VR of Korea. The three companies determined the final specification on the consumer version of the HMD and entered into fierce competition to take the lead in the HMD market with the size of $5.1 billion ahead of releasing new product in the first half of[10]. The characteristics of HMD DEVELOPMENT AND Feature are presented in Table 2.

2.2. General feature of HMD

The modern HMD may be defined as the device for VR display mounted on the head and device to experience the VR[12]. The HMD image implementation method depends on the display type and image generation method. 1. It consists of the monocular HMD and binocular HMD depending on the display type. 2. It is proposed as the way showing the virtual image only or the way with the real image depending on the image generation method[13]. The HMD device type is categorized into the PC type, mobile attachment and console. 1. PC type: It is represented by Oculus Rift DK2, providing various contents and excellent resolution. The disadvantage includes the restriction in use due to the cable connection to the PC. 2. Mobile attachment: It is represented by Samsung Galaxy Gear VR, uses the existing mobile phone as the device and is free to move with the wireless connection. The disad-

Table 2. Hmd development11

Order	Production year	HMD Image	Product name & producer	Feature	Order	Production year	HMD Image	Product name & producer	Feature
1	1965 - 1968		Head mounted 3D dis-play / Ivan Sutherland	Surround user's eyes with 2 small cathode-ray tubes (CRTs) to pro-vide multidi-mensional image	2	1995		VFX-1 / Forte (US)	The world-first polymer organic diode micro display with the integra-tion of the personal TV, video and portable headset
3	1997		(Glasstron/ Sony(Japan)	It is the portable HMD with 2 LCD screens, video and ear-phone, firstly released to the US market. Sony has provided various models from 1997	4	2006		Sensics piSight HMD / Sensics	piSight 24 is the micro display SVGA, in-troducing optical tile multiple display and providing the resolu-tion of 6 million pixels.
5	2012	 	Oculus Rift) DK1 / Oculus VR (:Palmer Luckey)	It provides the vision of the direction of head movement in real time and left and right lenses provide concave panorama display image	6	2013	 	HMZ-T3W / Sony (Japan)	Wireless connection with the WirelessHD for good sound quality and high quality wireless video transmission technology
7	2014		Oculus Rift) DK2 / Oculus VR (:Palmer Luckey)	It consists of the foam padding, lens, lens fixture, tube, HD display, electric circuit boards and cover and provides wide angle view like panorama through curved screen.	8	2015		Galaxy Gear VR / SEC	It is the portable attachable type, pro-viding much clearer 3D 360° image through the QHD AMOLED display, comfort with ergonomic concept and additional power source.

vantage includes the slow response compared to the PC type and the battery shall be replaced. 3. Console: It is represented by Sony HMZ-T3W. It is interconnected with PS4 to enjoy various game contents. The disadvantage includes the purchase of console like PS4. The conditions to prevent the biggest hurdle of HMD-based VR contents, simulation sickness, are as follows: 1. Head tracking: It is the technology which recognizes the direction and speed of turning the user's head and the latency shall be recognized higher than 0.02 second. 2. HMD's FOV: It shall secure the angle of sight between 90 and 110 degrees. 3. Stereoscopic 3D: It shall introduce multidimensional video implementation to recognize 3D movement. 4. Positional tracking: The technology which understand

Table 3. Cases analysis of 360° real image-based VR contents15

Contents image	Analysis contents			
	Title and producer	**Production technique**	**Experience**	**Genre and evaluation**
	Cirque du Soleil's Kurios / Felix and Paul Studios	360° real image	Experience the circus with fun, comedy, play and player in the wondrous space between the sky and earth, Cirque du Soleil as imaginary festival	Entertainment VR / Grade: 3.5 (from 264 users)
	Strangers with Patrick Watson / Oculus	360° real image	Experience the personal workshop of Patrick Watson by Felix & Paul Studio and watch Watson playing the piano	Entertainment VR / Grade: 3.5 (from 419 users)
	The Wild Within Dare / Destination BC	360° real image + UI interaction	Experience the Great Bear Forest in British Columbia along with central Pacific line	Natural scenery / Grade: 3.5 (487 users)
	Condition One / Condition One	360° real image	Enjoy Monument Valley, native American dance, walk and relax	Documentary VR / Grade: 3.5 (78 users)
	The Suite Life / Matterport	360° real image	Contents of hotel room interior and aircraft cabin with 360° images	Interior experience VR / Grade: 3 (189 users)

the user's position and movement shall be implemented. 5. High resolution display: The display of UHD4K (4128x3096), QHD (2560x1440) or higher is required.

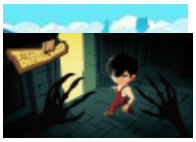
3. 360° VR Contents Case Analysis

Paul Milgram and Fumio Kishino proposed the virtual reality as a new digital environment with the digital entities and space on the opposite side of the Real Environment (RE) from the Virtual Continuity (VC) in the media center[14]*. The study analyzes the production method and features of the VR-based contents registered with the VR common platform for each case. There has been no systematic study on the VR contents production. Therefore, the study classifies 15 VR contents defined in the scope into 360° real images, 3D low-polygon-based VR contents and 360° animation VR contents and analyzes cases. The 3 classifications of production methods are the distinct feature of existing VR contents in the production.*

3.1 Case Analysis of VR Contents Based on 360° Real Image

The production methods of 360° real image-based VR contents consist of 360° general contents to unilaterally experience images taken with 360° real image, selective VR contents where the user selects and experiences contents through 360° sequence UI with several cuts and movable VR contents where the user experiences 360° image by following the line of sight of the camera. The contents of 360° VR images include circus, artist workshop, and natural heritage, documentary and interior. The advantages of the 360° real image in the case analysis may be introduced to special space or situations like the performance, play, architecture and cultural heritage. In particular, the 360° images of national heritage or cultural properties hold the value as historic evidence beyond VR contents. The disadvantages include impossibility for lighting display in the site and special skills and much time required in the post-production process like stitching or special effects.

Table 4. Case analysis of VR contents based on 3D low-polygon modeling[16].

Contents image	Analysis contents			
	Title and producer	**Production technique**	**Experience**	**Genre and evaluation**
	The BluVR / WEVR	3D low-polygon modeling + interaction	It is the cutting-edge 3D ocean simulation to fully experience the volume and depth and feel the ecosystem with various oceanic creatures.	Creature experience VR / Grade: 4 (from 2,444 users)
	GyeongjuVR / Clicked Inc	3D low-polygon modeling + interaction + simulation	Experience cultural heritage like Seogguram, Bulguksa and Cheomseongdae in Silla, ancient city of Korea	Heritage VR / Grade: 3 (from 826 users)
	COLOSSE / ColosseTeam	3D low-polygon modeling + interaction	It is the VR storytelling with 2D images Exploration story with the theme of great lost soul, fear, power and respect.	Illust movie VR / Grade: 3.5 (359 users)
	Totems In Dreamland / Mandrill VR Co.,Ltd	3D low-polygon modeling + interaction + simulation	The book about the legendary totem is used in the story and the player in the wonderland collects totems to fight against Orcs, dragons and mummies.	VR shooting game (light of sight and touch) / Grade: 3.5 (79 users)
	Speech Center / VRARlab	3D low-polygon modeling + interaction	Training simulation to cure anthrophobia. The user presents a lecture in the hall.	Anthrophobia training VR / Grade: 3.5 (152 users)

Cases analysis of 360° real image-based VR contents are presented in Table 3.

3.2. Case Analysis of VR Contents Based on 3D Low-Polygon Modeling

The production method of the VR contents based on 3D low-polygon modeling consists of the 3D low-polygon + simulation and 3D low-polygon + simulation + interaction. The 3D modeling is produced with less than 50,000 polygons for natural simulation in the VR environment and the surface is processed with 3D mapping to increase the rendering speed (latency of 0.02 second). It is mainly used in the mobile game. The contents are based on the oceanic creatures, national cultural heritage, VR game and practice. The advantage of the modeling includes the experience of various contents on the move and high physical presence and involvement. However, the disadvantage includes the poor sense of presence and detail due to lightly produced object with the 3D low-polygon modeling. Case analysis of VR contents based on 3D low-polygon modeling is presented in Table 4.

3.3 Case Analysis of 360° Animation-Based VR Contents

The production method of 360° animation-based VR contents is proposed with the mixture of the 360° animation + interaction and 3D hi-polygon + 360° real image technique. It uses Vray rendering program to implement sophisticated 3D object with 360° animation video or applies unreal engine to product, producing more qualified video contents than that of the 3D low-polygon or 360° real image. The contents may cover commercial movies, theater, cooking and driving. It may be used to promote and experience the movie and training for high video quality. The disadvantage includes much time for video production and fragmentary simulation and real-time interaction or major features of the VR. The usage is limited to the HMD for the PC with cable connection.

Table 5. Case analysis of 360° animation-based VR contents[17]

Contents image	Analysis contents			
	Title and producer	Production technique	Experience	Genre and evaluation
	Battle of Avengers Towervray / Framestore	360° animation + interaction	Transform to Iron Man in Empire State Building before the battle and experience the war with Thor's hammer and Captain America's Shield.	Entertainment VR / Grade: 4 (1919 users)
	Marvel Aven-gers: Tony Stark's Lab / Framestore	360° animation + interaction	Invite you to Stark Lab or Stark's Tower. Experience the AI, Iron Man's suites and various weapons.	Entertainment VR / Grade: 3.5 (734 users)
	WoofbertVR / WoofbertVR	3D high-polygon + picture + interaction	See or draw excellent pictures of Gauguin, Manet, Monet and Renoir in Courtald Institute of Art.	Experience-based education VR / Grade: 3.5 (175 users)
	Cyber Cook _ taster / Starship(UK) Ltd	3D high-polygon + interaction	Search for the world-first virtual kitchen, experience special cooking methods and realistically present cooking materials and process with high quality.	Experience-based education VR / Grade: 3.5 (82 users)
	It Can Wait Driving Simu-lation / AT&T Services, Inc.	3D high-polygon + 360° image + interaction	Train the risk of using mobile phone while driving	Driving training VR / Grade: 3.5 (212 users)

Case analysis of 360° animation-based VR contents are presented in Table 5.

4. How to Produce VR contents

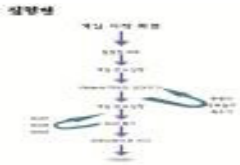
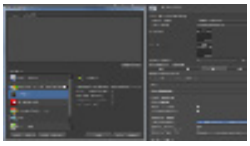
4.1 How to Produce 360° VR Contents

The 360° real image production technique includes the installation of Go-Pro cameras on camera holders to shoot 360° images and produces VR contents through stitching, editing and special effect processes. The production process of specific 360° real image video consists of the VR contents planning, 360° real image shooting, stitching and editing, VR environment configuration, building on the HMD and mobile publishing. Table 6 shows the workflow for each process.

4.2 How to Produce 3D Low-Polygon VR Contents

The 3D low-polygon VR contents production is used for relatively lightweight VR simulator and VR game production like mobile or casual games. The technique introduces simple modeling to reduce the data volume for more natural simulation of the 3D modeling or foundation for the VR contents. In particular, it is useful in the mobile HMD contents production requiring fast motion response speed through wireless connection. The contents producing consist of VR contents planning, 3D low-polygon 3D resources completion for the simulation, VR configuration, UIUX interaction formation and building and mobile processing processes. Table 7 shows the workflow for each process.

Table 6. VR contents production of 360° animation-based VR contents

Produced image	Producing	
	Workflow	Contents
	360° VR contents planning	Stitching: Stitch 7 images with the special stitching program to form a single 360° video. Special effect and image edit: Edit with VR plugin program to apply special effects to 360° images. VR contents production: Use the produced VR contents with the web or app supporting 360° images.
	360° real image shooting	Check the equipment: 7 Go-Pro cameras, holder, tripod, remote controller, slate, additional battery, SD card, etc. Location setup and camera setting: Set up the location for the 360° image and set up cameras. Shooting and file review: Block staff members before shooting, check the shooting status through the remote controller after shooting, check the shooting condition and review the file
	360° stitching and image editing	Stitching: Stitch 7 images with the special stitching program to form a single 360° video. Special effect and image editing: Edit with VR plugin program to apply special effects to 360° images. VR contents completion: Use the produced VR contents through web or app supporting the 360° image.
	VR environment configuration and VR equipment building	VR environment configuration: Form the UXUI for various interactions in the VR application engine environment VR equipment and mobile building: Build each VR equipment and mobile
	Contents production and publishing	Publishing: Publish and experience through proper logic and coding for each platform

4.3 How to Produce 360° Animation-Based VR Contents

The 360° animation VR contents production is good to implement high-quality PR image for the movie or game promotion trial version. The virtual space is easily produced by 360° animation tool of *Vray* a special program in rendering for special effects. In particular, the program shows better compatibility than other VR production tools and is lightweight, good for various VR device applications. The 360° animation VR contents producing process consists of the VR contents planning, 3D high-polygon resources completion for the animation, 360° animation implementation, VR configuration and UXUI interaction configuration, mobile and build and publishing. Table 8 shows the workflow for each process.

5. Conclusions

The VR contents are defined as 360° real image, 3D low-polygon VR contents and 360° animation depending on the production feature. The study proposed producing and specific workflow for each VR contents production technique. 1. The 360° VR contents are good for special space or condition, excellent in the physical feature and sense of reality and good for the historic evidence.

Table 7. How to produce 360° real image-based VR contents

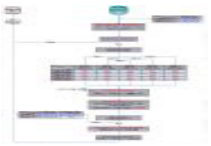
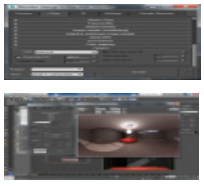
Produced image	Producing	
	Workflow	Contents
	3D low-polygon VR contents planning	VR contents planning: Brainstorming, production schedule discussion VR scenario organization: Story organization such as experience level, mission, etc. VR contents organization level: Organization with producer, planning system design, artist, developer, etc.
	3D resources completion	Low-polygon modeling: Produce the optimized modeling with a small number of polygons UV work: Resolve the 3D mesh to make 2D UV picture for coloring Animation: Character rigging and animating
	VR configuration and interaction	VR configuration: Set up the environment with the VR application engine Resources: Make the plot and background with low-polygon resources Play and additional effects: Additional effect programming like character and 3D animation GUI production and play manager connection: Form the GUI control and manager on the VR environment
	Contents com-pletion Mobile build publishing	Mobile VR build: Form the intro scene, place the GUI and build in mobile condition Publishing: Coding and logic publishing for each VR device

Table 8. VR contents production of 360° animation-based VR contents

Produced image	Producing	
	Workflow	Contents
	360° animation VR contents planning	VR contents planning: Brainstorming and production schedule discussion VR scenario organization: Story organization such as experience level, mission, etc. VR contents organization level: Organization with producer, planning system design, artist, developer, etc.
	3D resources completion	High-polygon modeling: Produce the modeling with the highest detail and quality Material editing and shader: Apply various light functions without the UV to form the material on the physical environment Animation: Character rigging and animating
	360° animation rendering and editing	VRAY configuration: VRAY pipeline and setting configuration 360° rendering: VRAY 360° setting configuration and rendering Special effect and image editing: Edit with VR plugin program to apply special effects to 360° images.

Produced image	Producing	
	Workflow	Contents
	VR configuration and interaction	VR configuration: Set up the environment with the VR application engine Resources: Make the plot and background with 3D high-polygon resources Play and additional effects: Additional effect programming like character and 3D animation GUI production and play manager connection: Form the GUI control and manager on the VR environment
	Contents completion Mobile build and publishing	Mobile VR build: Form the intro scene, place the GUI and build in mobile condition Mobile publishing: Coding and logic publishing for each VR device

The disadvantage includes impossibility for the lighting editing and requirement for special skills in the late production process. 2. The VR contents based on 3D low-polygon modeling enables the simulation and show high physical presence and involvement. The disadvantage is poor sense of presence and detail. 3. The 360° animation VR contents are provided as trial version for movies or games for use in advance. The high-polygon 360° animation productions enables various productions or defect of the real image technique and upgrades the image quality compared to the low-polygon animation. The disadvantage includes long period of production and fragmented interaction and simulation, major features of the VR. The VR contents production is proposed as 3 concepts based on the research result so far. However, it is found out that recent VR contents production mixes advantages of 3 production technique. For example, like Jurassic World of Felix and Paul Studios or Insurgent VR of Real FX, the technique has been evolved to maximize the efficiency and synergy in virtual experience like 360° real image background + 3D character + interaction or 360° 3D animation + low-polygon modeling character + interaction. The VR contents development would provide multilateral understanding of contents beyond spatial and time limits. The study would contribute to setting up the foundation for theoretical understanding of experience elements in the VR contents and developing direction technique to enhance experience elements.

6. Acknowledgment

"Funding for this paper was provided by Namseoul university".

7. References

1. The reality of virtual reality. http://www.enewstoday.co.kr/news/articleView. html?idxno=490178, 02/01/2016
2. Mobile to drive consumer adoption of virtual reality gaming. https://www.superdataresearch.com/blog/virtual-reality-market-brief/, 02/30/2016
3. Upcoming Virtual Reality Era. http://www.focus.kr/view.php?key=2015121800165511523, 02/01/2016
4. Vasudevan SK, Vivek C, Srivathsan S. An Intelligent Boxing Application through Augmented Reality for two users - Human Computer Interaction Attempt. Indian Journal of Science and Technology. 2015; 8(34):1-7
5. Sutherland IE. The Ultimate Display Proc. IFIP. 1968; 65(2):506-08.
6. Steuer, Jonathan Defining. Virtual Reality: Dimensions Determining Telepresence. Journal of Communication. 1992; 42(4):73-93.
7. VFX1 Headgear. https://en.wikipedia.org/wiki/VFX1_Headgear, 05/01/2016.
8. Sensics. http://sensics.com/. 02/01/2016.
9. Oculus. https://www.oculus.com/en-us/. 02/01/2016.
10. Mobile to drive consumer adoption of virtual reality gaming. https://www.superdataresearch.com/blog/virtual-reality-market-brief/, 02/30/2016.
11. Virtual Reality - With Demo Video. http://www.slideshare.net/nikeleerocks/virtual-reality-with-demo-video. 02/02/2016.
12. Head Mounted Display. https://ko.wikipedia.org/wiki/%ED%97%A4%EB%93%9C_%EB%A7%88%EC%9A%B4%ED%8B%B0%EB%93%9C_%EB%94%94%EC%8A%A4%ED%94%8C%EB%A0%88%EC%9D%B4, 02/01/2016.
13. Never Dictionary. http://dic.naver.com/search.nhn?dicQuery=%ED%97%A4%EB%A6%AC%ED%8B%B0%EC%A7%80&query=%ED%97%A4%EB%A6%AC%E

D%8B%B0%EC%A7%80&target=dic&ie=utf8&query_utf=&isOnlyViewEE=, 04/27/2016

14. Milgram P, Kishion F. A taxonomy of mixed reality visual display :Special Issue on Networked Reality. IEICE Transactions on Information and Systems. 1994; 77(12):1321-29.
15. Oculus experiences. https://www2.oculus.com/experiences/rift/. 03/30/2016.
16. Oculus experiences. https://www.oculus.com/en-us/gear-vr/, 03/30/2016.
17. Oculus experiences. https://www2.oculus.com/experiences/rift/. 03/30/2016.