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A Brief Understanding About Quality Metrics in Virtual Reality

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***Abstract*: Virtual reality renders the objects generated by computer to create a virtual environment to the users. As years have passed, virtual reality has evolved in terms of use of its technology and immersion level provided to users. There are various types of virtual reality devices in market and each one varies in its performance. This makes it important and difficult to assess the performance of virtual reality devices. In this paper, we give a brief insight about the virtual reality rendering and virtual reality hardware quality metrics, how it affects the performance of virtual reality products and how to tune these to get an ideal virtual reality experience.**

***Keywords*: Head mount device, virtual reality, motion to photon, asynchronous time warping, peak signal to noise ratio**

1. Introduction

Virtual reality is also called as “Near reality”, virtual means near and reality is what human beings experience in their life. Virtual reality gives the feel of complete immersion to a user who is experiencing it. It is an interactive computer-generated experience taking place within a simulated environment with both audio and visual feedback. Virtual reality makes human interaction better with the machines by using stereoscopic vision and senses of hearing, touch and smell very similar to the real world within a confined space. It uses high performance computing powered GPUs and processors, head mount device (HMD) and controllers to achieve complete immersion. Virtual reality now has applications spread across various domains – military, gaming, real estate, education, health care, heritage etc. Measuring and analyzing the performance of VR systems is a essential task but it is not a simple task as these HMDs are not easily accessible. Moreover, VR systems have multiple entities including HMDs, rendering devices like desktops or smartphones, VR applications and internal algorithms used. In this paper, we describe about various quality metrics in virtual reality system and how all these factors affect the performance of the VR system. Section 2 describes the related work done in measuring these quality metrics, section 3 describes various quality metrics to be considered in virtual reality and section 4 gives the conclusion.

2. Related work

In this section, summarization is being made about the subjective tests carried out by various authors to know about the quality metrics and how it the affects the performance of the VR systems. Chun-Ming Chang et al. [1] proposed an experiment to measure positioning and timing accuracy in virtual reality setup. Numerous performance metrics on positioning and timing accuracy were taken, and detailed experimental setup and steps were presented. Timing accuracy is measured using latency factor and positioning accuracy is measured by considering spatial inconsistency between physical moves and visual feedback in terms of precision and sensitivity. [1]

Jingbo Zhao et. al. [2] proposed a method to find M2P latency in HMDs. He designed the experiment to introduce damped sinusoidal motion to the headset by mounting the HMD on a pendulum and observed the sinusoidal motion when the pendulum swung. Then, the phase shift between the captured signals of the physical motion of the HMD and a motion-dependent gradient stimulus rendered on the display was calculated and this was concluded as latency. [2]

Sebastian Schwarze et. al. [3] presented the paper on the difficult situations encountered with respect to immersive media quality assessments. They presented the objective and subjective evaluation of HEVC main profile compatible depth map compression on the perceptual quality of 6DOF immersive video. Objective results pointed at a benefit for encoding depth at a higher quality as the corresponding texture. However, the subjective evaluation could not confirm this. [3]

Sara Vlahović et. al. [4] showed how the observation about overall QoE, immersion, and physical discomfort felt by traditional tunneling locomotion, first-person locomotion, and gesture-based locomotion in a study with different levels of experience on 29 participants. It was observed that participants showed a preference for continuous movement and non-limited field of view and rated controller based as the most immersive, followed by human joystick locomotion. [4]

3. Quality metrics

The performance of a virtual reality system is measured based on the hardware characteristics (device properties) and software characteristics (rendering). Better the performance, better experience for the user. VR manufacturers will do all these subjective tests and benchmark their product using these

key performance index (KPI) quality metrics. The below fig. 1, gives the classification of software (render) quality metrics.

Field of View – Field of view (FOV) is the extent of the observable environment at any given time. It is how much screen depth and at what range a user can perceive immersion. Wider the angle of field of view, greater immersion the user experience. Many of the VR headsets has 110 degrees FOV and it seems to be ideal for the immersion.

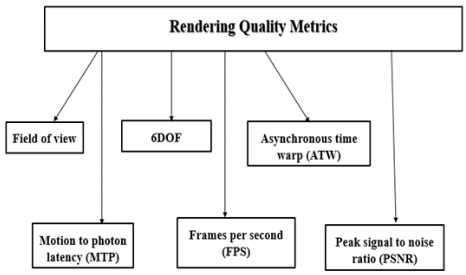

Fig. 1. Rendering quality metrics

Motion to photon latency – Motion to photon latency, often known as M2P is a very critical aspect in VR. It is the total time taken to reflect the content with respect to user's movement (current position of user) on the screen. The ideal value for m2p is less than 20ms. Within this value, the mind can be convinced that it is in immersed in virtual environment and it is in presence state. If the value exceeds 20ms, VR sickness and nausea is caused to the user as there will be a screen lag and user feels disorientation between real world and virtual world.

M2P latency can be reduce by increasing the refresh rate (Number of times the content is redrawn on the screen in one second), prevent GPU buffering, time warping or ATW and capturing head movement using sensors.

Six Degrees of Freedom (6DOF) – Previously, HMDs used to track the head movements of the user – left, right, up and down and this was called as 3 degrees of freedom (3DOF). But it failed to track the position of the user and used to assume that the user was still. To overcome this, 6DOF concept came where the headset could track all the head movements as in 3DOF, as well as the user's position as he moves towards left, right, front and back.

Frames Per Second (FPS) - Frames per second can be defined as the number of frames that are rendered on the display unit in one second. Generally, normal videos are played at 30 FPS, whereas VR devices require 60 FPS at least to give a cinematic and immersive experience. There must not be much difference between encode and decode fps.

Asynchronous time warp (ATW) – It is a technique used to reduce motion to photon latency. It generates intermediate frames in situations when the game can't maintain frame rate, helping to reduce judder. It does this by mathematically predicting the frame, which avoids the extensive load on CPU and GPU, else it would have been slower with all the rendering commands to be issued. Although ATW reduces the latency, it produces many duplicate frames with different timestamps in the process. If a greater number of duplicate frames are produced, then it decreases the efficiency of the system.

Peak signal to noise ratio (PSNR) - The PSNR, also known peak signal-to-noise ratio, is the ratio between peak signal and noise in decibels calculated between two images. This is used the measure the quality between original image and compressed image. Greater the value of PSNR, quality of compressed image is better.

The below fig. 2, gives the classification of device specific quality metrics

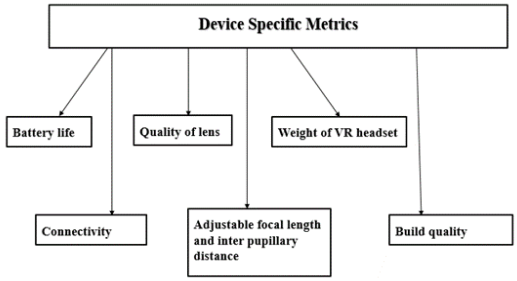

Fig. 2. Device specific quality metrics

As mentioned in the previous topics, virtual reality is a technology used to provide complete immersive experience to the user. One can watch 3D or 2D movies, play video games, view 360-degree videos etc. and can feel their actual presence in these environments. These are all achieved by with the help of VR headset, called as a head mount device (HMD). These headsets are generally made up of plastic, cardboard, fibers. It usually has two spherical lenses to magnify the video content and show to user as if they are happening around them. Also, it uses tracking sensors like gyroscope, accelerometer, magnetometer etc. to track the user in the real world and map the position in virtual world.

The description of the qualities of a headset that decides VR capabilities mentioned in figure 3.1 are given below.

- *Battery life* – Virtual reality rendering is a compute intensive job and it consumes lots of GPU power for the same. This in turn leads to more battery power consumption and device heats up rapidly. A user cannot always plugin to charging mode when he is playing a game on the VR headset. Hence better battery optimization techniques should be used for better battery backup, less heat dissipation and fast charging modes must be enabled.
- *Connectivity* - Virtual reality devices can be used in tethered or untethered mode. Both modes have its own advantages and disadvantages. In tethered mode, latency will be less as there is a wired connection between the headset and the server (PC) and user movement is restricted to a small area due to wires. Whereas in wireless mode, latency will be a bit higher than tethered mode, but the user can walk freely

around the room without being disturbed by the wire. Currently there are both kinds available in the market.

- *Quality of lens* - Lens in the VR headset plays a major part as that gives the quality of rendering. Some of the headsets which are cheap and are based on Google Cardboard come with plastic lens. However, greater the lens quality, greater the picture is. Majority of the lenses used in VR headsets are made up of spherical lenses with several layers of Nano coating and HD optical ABS quality which minimize eye fatigue, cyber sickness and image deformity in long use. An ideal VR headset should have crystal clear and bigger lenses to enable complete immersion.
- *Adjustable inter pupillary distance and focal length* - Some VR headset has fixed lens, whereas in some we can adjust both inter pupillary distance and focal length. Adjustment of inter pupillary distance and focal length is generally done to help person having near sightedness or far sightedness to enjoy virtual reality experience and to fit the clarity of image.
- *Weight of VR headset* - Weight of the VR headset is the second most important factor after lens. Lighter the headset, comfortable to use it for longer duration. Generally, a VR headset weighs from 120gm to 350gm. If weight of the headset is more, then wearing it for around 20 mins puts pressure on the nose and becomes uncomfortable to wear. An ideal VR headset must be light in weight.
- *Build quality* - Build quality is an important aspect as user the comfort level depends on it. Build quality of a headset is the type of material and quality of the material used to make the headset. Generally, headsets are made from plastics or fibers that are of light weight. Cushion foam around the edges makes the usage more comfortable and one feels less strain on eye and nose.

4. Conclusion

Virtual reality is one of the emerging technologies in the present decade, it uses high computing resources to generate create a simulation of 3D world and projects it on the virtual reality headset. There are various types of virtual reality devices in market and each one varies in its performance. In our proposed paper, brief description is given about how to assess the performance of a VR device and what qualities should be considered. A general idea is given about VR rendering quality metrics, how each metric affects the rendering in VR device, what effect they can cause to the user and how they can be minimized. Also, from hardware quality metrics perspective, insights are given about the manufacturing and physical design of the HMD, how these should be designed in an ideal VR so that user has a pleasant and comfortable experience.

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