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Design Infrastructure for Measurement & Analysis of Parameters that affect VR Performance & User Experience

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ABSTRACT: Virtual Reality (VR), which can be referred to as immersive multimedia or computer-simulated life, replicates an environment that simulates physical presence in places in the real world or imagined worlds and lets the user interact in that world. Virtual reality artificially creates sensory experiences, which can include sight, hearing, touch, smell, and taste. Many games have been developed by the game developers. Also, several concerns are associated with performance of these games, like the frame rate by which the frame is displayed on the screen, the latency while displaying the frame, the resolution of the display and many more. The proposed system is then used to monitor these factors based on the changes made to the underlying driver, system or the game and by capturing each frame and then do comparison with the previous result available by showing a graph for the same. This is used to generate a report for measuring the performance of the game.

KEYWORDS: Virtual Reality, Oculus Rift, HTC Vive, FPS, Frame Rate, KPI

I. INTRODUCTION

Virtual reality (VR) is a term that applies to computer-simulated environments that can simulate physical presence in places in the real world, as well as in imaginary worlds. In other word, virtual Reality is a simulation in which computer graphics is used to create a realistic looking world. Virtual Reality is a real-time and interactive technology. It means that the computer can detect user inputs and modify the virtual world instantaneously. Interactivity and its captivating power contribute to the feeling of being the part of the action on the environment that the user experience.

Today things are very different. It is not until recently that our ever-increasing technological capability finally made VR accessible with the emergence of high performing hardware capable of efficiently handling various types of workloads. This is mainly due to:

- High resolution displays offering crisper images and realism.
- Sensor technology which enables more immersive VR experience and control such as gyros, accelerometers etc.
- Advanced microprocessors capable of executing complex calculations and functions, or delivering energy efficient visually stunning graphics.

Today, VR is touted as one of the 'most disruptive' technologies for the next decade, with a plethora of competing devices already in development, including: Oculus Rift, Sony VR, HTC Vive, OSVR Razer, Samsung Gear VR among others, vying to perfect this revolutionary new technology and make it ubiquitous.

This immersive technology represents the next generation of gaming, where the traditional ethos of bodiless minds communicating via keyboard and screen are replaced with the notion that the senses are primary causes of how and what we know, think and imagine.



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VR headsets like Oculus Rift and PlayStation VR are often referred to as HMDs and all that means is that they are head mounted displays. Even with no audio or hand tracking, holding up Google Cardboard to place your smartphone's display in front of your face can be enough to get you half-immersed in a virtual world. When using a headset, the content of the actual games also matters. In virtual reality, players can lean over and look at something up close. Such scrutiny requires better graphics to be believable. The goal of the hardware is to create what appears to be a life size, 3D virtual environment without the boundaries we usually associate with TV or computer screens. So, whichever way you look, the screen mounted to your face follows you. This is unlike AR which overlays graphics onto your view of the real world.

One important way VR headsets can increase immersion is to increase the field of view i.e. how wide the picture is. A 360-degree display would be too expensive and unnecessary. Most high-end headsets make do with 100 or 110-degree field of view which is wide enough to do the trick. And for the resulting picture to be at all convincing, a minimum frame rate of around 60 frames per second is needed to avoid stuttering or users feeling sick. The current crop of VR headsets go way beyond this - Oculus is capable of 90fps, for instance, Sony's PlayStation VR manages 120fps.

Head-tracking tech needs low latency to be effective - we're talking 50ms or less or we will detect the lag between when we turn our head and when the VR environment changes. The Oculus Rift has an impressively minimized lag of just 30 milliseconds. Lag can also be a problem for any motion tracking inputs such as PS Move-style controllers that measure our hand and arm movements.

II. RELATED WORK

Nowadays computer graphics is used in many domains of our life. At the end of the 20th century it is difficult to imagine an architect, engineer, or interior designer working without a graphics workstation. In the last years, the stormy development of microprocessor technology brings faster and faster computers to the market. These machines are equipped with better and faster graphics boards and their prices fall rapidly. It becomes possible even for an average user, to move into the world of computer graphics. This fascination with a new (ir)reality often starts with computer games and lasts forever. It allows to see the surrounding world in other dimension and to experience things that are not accessible in real life or even not yet created. Moreover, the world of three-dimensional graphics has neither borders nor constraints and can be created and manipulated by ourselves as we wish – we can enhance it by a fourth dimension: the dimension of our imagination. [1]

But not enough: people always want more. They want to step into this world and interact with it – instead of just watching a picture on the monitor. This technology which becomes overwhelmingly popular and fashionable in current decade is called Virtual Reality (VR). The very first idea of it was presented by Ivan Sutherland in 1965: “make that (virtual) world in the window look real, sound real, feel real, and respond realistically to the viewer’s actions” [1].

Virtual Reality (VR) is an immersive computer system that mimics the world we see around us. It can also be used to create imaginary worlds, or in other words it can be used to create immersive games. VR isn't a new idea, in fact it was first described in the 1930s, and the first VR system was built in the late 1960s. Its boom time came in the 1990s with companies like Sega and Nintendo started developing consumer level VR gaming products. However, after a boom, there is often a bust. And that is what happened to VR. Sega's product was never release, and Nintendo's Virtual Boy was a commercial failure. [13]

Since then very little has happened at a consumer level. The reasons for VRs failures in the 1990s were not only to do with computing power. Think back to the size and design of laptops and mobile phones in that era. To make VR headsets truly useful the technology in terms of miniaturization, displays, materials and computing power needed to improve. [13]

Frame rate, also known as frame frequency, is the frequency (rate) at which an imaging device displays consecutive images called frames. The term applies equally to film and video cameras, computer graphics, and motion capture systems. Frame rate is usually expressed in frames per second (FPS). [15]

There are three main frame rate standards in the TV and digital cinema business: 24p, 25p, and 30p. However, there are many variations on these as well as newer emerging standards. Frames per second are often expressed as hertz (1 Hz = 1 Fps). [15]



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- **24p:** is a progressive scan format and is now widely adopted by those planning on transferring a video signal to film. Film and video makers use 24p even if they are not going to transfer their productions to film, simply because of the on-screen "look" of the (low) frame rate, which matches native film.
- **25p:** is a progressive format and runs 25 progressive frames per second. This frame rate derives from the PAL television standard of 50i (or 50 interlaced fields per second). Film and television companies use this rate in 50 Hz regions for direct compatibility with television field and frame rates.
- **30p:** is a progressive format and produces video at 30 frames per second. Progressive (noninterlaced) scanning mimics a film camera's frame-by-frame image capture. The effects of inter-frame judder are less noticeable than 24p yet retains a cinematic-like appearance. Shooting video in 30p mode gives no interlace artifacts but can introduce judder on image movement and on some camera pans. The widescreen film process Todd-AO used this frame rate in 1954–1956.
- **48p:** is a progressive format and is currently being trialed in the film industry. At twice the traditional rate of 24p, this frame rate attempts to reduce motion blur and flicker found in films. Director James Cameron stated his intention to film the two sequels to his film Avatar higher than 24 frames per second to add a heightened sense of reality. 50i is an interlaced format and is the standard video field rate per second for PAL and SECAM television.
- **60i:** is an interlaced format and is the standard video field rate per second for NTSC television (e.g., in the US), whether from a broadcast signal, DVD, or home camcorder. This interlaced field rate was developed separately by Farnsworth and Zworykin in 1934, and was part of the NTSC television standards mandated by the FCC in 1941.
- **50p/60p:** is a progressive format and is used in high-end HDTV systems. While it is not technically part of the ATSC or DVB broadcast standards yet, reports suggest that higher progressive frame rates will be a feature of the next-generation high-definition television broadcast standards. Many modern cameras can shoot video at 50p and 60p in various resolutions. YouTube allowed users to upload videos at 60fps in June 2014. YouTube also allowed full HFR videos previously uploaded before 2014.
- **72p:** is a progressive format and is currently in experimental stages. Major institutions such as Snell have demonstrated 720p72 pictures as a result of earlier analogue experiments, where 768 line televisions at 75 FPS looked subjectively better than 1150 line 50 FPS progressive pictures with higher shutter speeds available (and a corresponding lower data rate). Modern cameras such as the Red One can use this frame rate to produce slow motion replays at 24 FPS.
- **90p:** The HTC Vive and Oculus Rift are virtual reality headsets that refresh at 90 Hz.
- **100p / 119.88p / 120p:** are progressive-scan formats standardized for UHD TV by the ITU-R BT.2020 recommendation. Various cameras including GoPro, Sony and JVC can shoot video at 720p and 1080p at 120p. There is an array of modern monitors that have refresh rates capable of 120 Hz which allows users to view content at 120 FPS. Project Morpheus which is a virtual reality headset to be released in October 2016, can display content at 120 fps.
- **144 - 240 fps:** CRT displays and modern PC gaming monitors can display 144 Hz through 240 Hz. 240fps is also around the limits of perceivable smoothness.
- **300 fps:** interpolated 300 FPS along with other high frame rates, have been tested by BBC Research for use in sports broadcasts. 300 FPS can be converted to both 50 and 60 FPS transmission formats without major issues. 300fps is also the maximum frame rate for the HEVC format.

Oculus, the company at the forefront of the virtual reality revival, described presence as “The unmistakable feeling that you’ve been teleported somewhere new. Comfortable, sustained presence requires a combination of the proper VR hardware, the right content and an appropriate system.”[7]

Believable experiences in virtual reality come at a price. “The reality is that VR is more demanding than any other type of gaming we’ve ever had,” said Palmer Luckey, Oculus founder. It has taken Oculus years to get the headset and its accompanying software just right. [7]

The issue is that VR has to be smooth, so when a player moves his head, the picture reacts quickly and believably. [7]



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While television shows run at 30 frames per second (fps) and some console games run as high as 60 fps, the Oculus Rift runs at 90 fps to make the virtual world feel seamless. “When you are trying to do 90 frames per second, stereo 3D, over-1080p resolution, and have a very wide field of view at the same time? It’s just a lot of things to stack on top of one another,” Luckey explained. While a computer runs these extreme graphics, it also processes data from the movement of the user’s head and body (picked up by a camera sensor) and 3D audio that adjusts to the user’s movement. That’s all while processing input from controllers, too. [7]

Expanding more on how FPS and refresh rate work, FPS and the refresh rate of a monitor are two separate things independent from each other. Frames per second is how fast your GPU can display images, per second. 60 FPS means that the GPU is outputting 60 images every second. The refresh rate of a monitor is how fast the monitor can display images per second, measured in hertz (Hz). This means that if you are playing a game and the FPS is 120 but your monitor refresh rate is 60 Hz, you will only be able to display 60 FPS. You are essentially losing half of your frames, which is not a good thing as “tearing” can occur.

Tearing is the phenomenon of objects in a game breaking up into a few pieces and being displayed in two different locations along the X axis giving a tearing effect. This is where Vertical Sync (VSync) comes in. This limits the framerate to your monitor’s refresh rate. This way no frames are lost and in turn no tearing is experienced. Therefore, for the best VR experience, the same number for the frame rate and refresh rate need to be achieved, or sickness can occur. [12]

There are many tools which are widely used to measure the frame rate in virtual reality games. Each of these tools is a separate combination of hardware and software. The key to VR looking good and feeling comfortable to a user is a smooth and stable frame rate. They are used to test a VR system’s ability to deliver a consistently high frame rate regardless of the level of quality and type of content. Aside from the frame rate, there are many new VR benchmarking tools that measure frame latency and the responsiveness and accuracy of the sensors in the headset.

FRAPS:

Whether you want to capture a highlight reel of your elite gaming skills, or just visual proof of your winning high score, FRAPS is the tool for you. This capable application can snap still-image screenshots or capture full-motion video from videogames (or other 3D applications) with a minimal impact on system performance--giving you the best quality output possible from a third-party program.

In addition, FRAPS can also benchmark and help you tune your graphics system performance while a 3D game is running. The program, runs in the background while you play, keeps track of and log the video framerate your game is displaying through the graphics board.

FCAT (Frame Capture Analysis Tool):

FCAT is essentially a collection of tools, but at its most fundamental level FCAT is a simple, yet ingenious method to measure frame latency at the end of the rendering pipeline. FCAT is essentially a 2-part solution.

In-between the graphics cards DVI output and the monitor FCAT place a hardware based solution frame grabber. That is a PCIe card able to capture each frame coming from the DVI connector. Not a cheap method, as to be able to capture 1920x1080 or 2560x1440 at say 60 FPS/hz it needs powerful hardware and the capture card it uses is 1500 EUR alone. Once we set this configuration up we can record the data coming from that gaming PC, then analyze and interpret it. The framegrabber method merely is interesting to see weird graphics card behavior like stuttering, visible anomalies that we try to poll and chart.

FCAT provides a clear picture of what’s happening at the end of the rendering pipeline, giving us for the first time an automated, quantitative look at frame intervals, stuttering, and more. FCAT is quite simply the frame interval analysis tool. It is the tool that will enable us to analyze stuttering, micro-stuttering, and more, in a manner consistent with benchmarking methods and core beliefs in the scientific method.

III. PROPOSED SYSTEM

In virtual reality applications, there is an aim to provide real time graphics which run at high refresh rates. However, there are many situations in which this is not possible due to simulation or rendering issues. When running at low frame rates, several aspects of the user experience are affected. For example, each frame is displayed for an



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extended period, causing a high persistence image artifact. The effect of this artifact is that movement may lose continuity, and the image jumps from one frame to another.

In this system, we are going to trace the various Key Performance Indicators like the average number of delivered frames per second, average number of unconstrained frames per second, the percentage of stutter, the number of frames missed and the actual latency in showing the user content. We are going to create an application which will automatically on nightly basis will install the latest build of the driver, run the game, collect the various Key Performance Indicators and will display the analysis of the data along with the past data collected.

Virtual Environment (VE) effectiveness is often measured in terms of application success, e.g. task performance or training transfer, or is measured by the degree to which the VE creates a subjective illusion of presence – a sense of “being there” in the virtual world. VE effectiveness can also be evaluated by the extent to which the system minimizes or eliminates factors that hinder user performance and/or break the user’s sense of presence, e.g. simulator sickness or latency.

Virtual reality complicates this: if you record a video of the content displayed on your VR headset and simply play it back on someone else’s headset, a host of problems arise. First, differences between headsets (or even user settings) can result in distortion, artifacts, and problems with convergence. Second, because the original player is in control of head movement, not the person viewing the content, they feel as though their head is being forcibly turned to look around the scene, a sensation that often induces VR sickness. The problem can be circumvented by simply watching the recorded content on your monitor instead, but that’s no fun – what you really want is for others to be able to experience those virtual worlds in VR, the same way that you did during play.

Key Performance Indicators can also be used as a point of comparison to other systems with similar specifications, which lets you see if your computer is operating the way it should or if there is perhaps something holding it back. Latency and frames per second play a significant role in the comfort and enjoyment of a VR experience. We are going to use a tool to find out how well these KPI’s are working in VR games. We will then present these numbers we generated and do our best to correlate them to our real-world experience gaming with the Rift.

In general, to calculate the FPS, you need the following:

- **cn**: counter of how many frames you've rendered
- **time_start**: the time since you've started counting
- **time_now**: the current time

To calculate the FPS, you simply evaluate this formula (all taken from this answer):

$$\text{FPS} = \text{cn} / (\text{time_now} - \text{time_start})$$

One thing that often greatly influences the run-time and therefore the FPS is whether you are running a debug or release build. The debug builds are often slower by multiple order of magnitudes, since they contain a lot of additional information and checks that help with the debugging process while slowing the application down considerably.

Regarding concrete FPS quantity, there is no way for to tell whether that value is "ok" since it depends on so many factors that we don't know about, such as your system in general, the current resource usage by other processes / applications, etc.

Vertical synchronization (Also vertical sync or VSYNC) separates the video fields. The vertical sync signal is a series of much longer pulses, indicating the start of a new field. The sync pulses occupy the whole of line interval of several lines at the beginning and end of a scan; no picture information is transmitted during vertical retrace. The pulse sequence is designed to allow horizontal sync to continue during vertical retrace; it also indicates whether each field represents even or odd lines in interlaced systems (depending on whether it begins at the start of a horizontal line, or midway through).

The goal of Virtual Reality is to give users the most immersive experience that technology will allow. It’s all about creating a true sense of presence within a virtual world that blends seamlessly with our own reality. From a technological perspective, HTC and Oculus achieve this by using a refresh rate of 90 Hertz, thereby requiring the content ideally be rendered at 90 frames per second. By hitting this frame rate, you are ensured the smoothest and most immersive experience. Not only is the experience more life-like, it’s also the most comfortable. If your frame rate drops below 90 fps, the chances of “simulation sickness” are significantly increased.



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Maintaining frame rate is incredibly important because VR amplifies even the smallest lapses in performance. These lapses, no matter how small, instantly disrupt the users' connection to the virtual world around them. Not only does this ruin the heightened sense of presence that VR is designed to provide, it can also cause a very unpleasant feeling of nausea. Mike Nash (VP of customer experience and portfolio strategy at HP) explains it well; "If you don't get the performance right, you can actually get kind of nauseous because you're getting an experience that is not fluid... The whole thing about virtual reality is, your eyes and the device are playing a trick on your brain. If you don't execute that trick flawlessly, it can make you a little bit motion-sick." Essentially, if you move and the virtual world around you don't keep up with that motion your brain instantly recognizes that something is wrong and self-preservation by making you feel sick.

So, this system is basically used to monitor the FPS parameter and to check the other KPI that could affect the actual performance of the game. This system is basically used to monitor what change will break the performance of the game. It could be used to test the driver changes, the actual game code changes to determine whether the game performance has been affected. Also, it can be used to test all the benchmark games for Oculus as well as any other virtual reality games and can be used to generate Smoothness Metrics and integrate the timestamp generation to debug the performance of the game. Since both Oculus Rift and HTC Vive are working with refresh rate 90hz the 95th percentile should be 11,11 ms of less in ideal situation. Some games (depending on genre) may work with good UX even with 60 or 45 average fps. So, all such performance measures can be detected using the above system.

IV. CONCLUSION

Virtual reality allows the user to be immersed into a virtual world, unlike regular screens in front of the user which do not allow for such an experience. VR can include 4 of the 5 senses, including vision, hearing, touch and possibly even smell. With this power, VR can take people for a virtual world easily.

This system is to develop an architecture where the display can be measured more specifically. We want to trace the default behavior of display frames by a programmable layer that can execute a custom program for every individual display frame. This layer should run independent of the application in such a way that the generation of new application frames is not postponed and can measure the various key parameters and can conduct an analysis by comparing the results collected per nightly checking with the previous results that are already available.

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