Research in Virtual Reality

Graphics

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Summary

Graphics have been a key component to video games since their dawn. Modern day video game graphics have developed so much since their earliest days, from representing asteroids with nothing more than lines to near photorealistic recreations of entire cities made of millions of polygons and effects. Video game graphics have always gotten better, whether that comes from improved art direction or advances in computer hardware, it has almost always gotten better over the years. Virtual Reality is a rare case in which the perceived graphics quality of video games has decreased. This is mainly due to the fact that for a VR game to work you essentially have to run a game that you would have been running at 30 FPS, at a whopping 180 FPS. The same graphics processor you were working with before now has to run twice the number of screens, at 3 times the framerate, in order to give the user both a 3D and smooth enough image as to avoid nausea and create adequate immersion. In this paper I will attempt to find possible solutions to this drastic change in graphics quality, by leveraging style and hardware ability.

In the following sections we will look at different attempts and techniques to visual representation in VR gaming. By the end we will have determined the optimal style to pursue with the resources available to small scale developers like myself.

Realistic Graphics

Truly realistic graphics are and have been a goal for gaming since the beginning. Game developers have been attempting realistic graphics since we got access to 3D graphics with consoles like the *Nintendo 64* and *Playstation*, but have only really achieved realism two generations later on the *PS3* and *Xbox 360* systems. Today, games with extremely realistic 4K graphics are possible using powerful consoles and PC GPUs. Unfortunately, when it comes to Virtual Reality, we have to backtrack to graphical quality that doesn't even look quite as good as the *PS3* and *Xbox 360* era. This has to do firstly with the high demand VR has on graphics processors, but it also has to do with the fact that we are strapping a 1080 x 1200 resolution screen right to our faces, making their lower pixel count even more apparent.

This is why realistic graphics in Virtual Reality seem to fail, we are used to a certain standard in quality and we do not get this in VR, although we do get huge improvements in input and immersion, it's not enough to forget about what we are looking at. There is however, a solution, if we go back and look at what techniques were used when developers were faced with limited computing power in the past.

Simple Graphics

In order to create immersive gameplay for virtual reality, we must look back in time, to the early days of 3D, when developers saw endless potential for a technology, but had to use simple graphics due to their limited hardware. Graphics in games like Super Mario 64 for the Nintendo 64 still hold up today as they did not try and do what the hardware couldn't. The game still looks relatively sharp and the style is undeniably fun over 22 years later! This is the approach we need to take when developing for VR, simple yet crisp. There are various examples in VR games that achieve this effectively, such as *Rec Room*, a cartoony multiplayer game that focuses more on social interaction and gameplay than it does on graphics. Even games like *Lone Echo*, that *feel* realistic, actually have a relatively simple graphics style, its the immersion that the game provides that makes it feel real, and this is due to the developer's awareness of the platform they are developing for. The greatest benefit of adopting a simple style for a game developed by such a small team (1-2 people) is that it is a much less expensive and much easier than producing realistic graphics.

*There are 3 techniques/strategies that will make simple graphics effective in virtual reality. These include **post processing**, simple **texturing**, and **super-sampling** resolution.*

Post Processing

The Unity engine and the Unreal engine are the two primary VR game development tools, both having many built in features supporting the medium. Unreal typically produces more realistic graphics, and Unity has more resources for developing simple graphics styles. Therefore Unity is the optimal engine for small team, simple graphic VR applications. Unity has a robust collection of post processing effects that make the low resolution, non antialiased shapes in your scene a little more pleasant to look at. The effects available include; depth of field, color correction, bloom and many more. These effects go a very long way when working with simple graphics.

Texturing

Finding a good balance between simple and detailed textures is important in VR. If you were to use textures that are very high resolution, and very detailed, it would be wasted computing power, as the current gen VR headsets have trouble showing this detail. However if you were to go too simple, for example just having solid colors as your textures, the game would feel incomplete, as I've found with many of my unfinished games. The ideal combination for VR texturing is to have a texture that has some kind of simple pattern on it. Games that do this well are *Climbey* and the Echo VR series (*Lone Echo, Echo Arena, Echo Combat)*. Below is an example of the texturing in *Climbey*.

As you can see in this texture, you have what appears to be a simple white surface, but as you inspect it you see very small dots. This creates an immersive texture that you can believe. While the graphics of the game in general feel simple, the balance of this simplicity with detail creates the perfect VR graphical experience.

Super-Sampling

Super-sampling is the process of rendering your game at a higher resolution than your hardware is capable of. This results in a slightly sharper image. In traditional video games the effect is negligible as there are already millions of pixels in your field of view. Because VR involves strapping a screen to your face, pixel density becomes a much more important factor. The added sharpness of even 20% increased resolution makes a world of difference in the long run. The problem with this is that if you super-sample by 1.2x then you need 1.2x the power in your graphics processor! This is why making your game with simple graphics helps, not only will players with very capable graphics cards be able to enjoy your game at increased resolution, but players with weak graphics cards won't be left in the dust. Everybody wins!

1.0x vs. 2.0x super-sampling

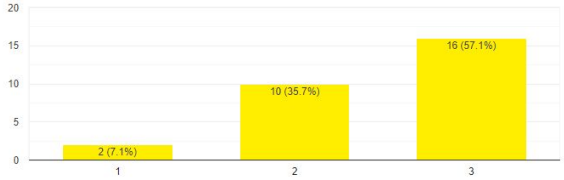
Abstract Graphics

Abstract graphics are very effective in virtual reality and I am exploring them for a few of my VR art installations. Graphics are abstract when nothing about them resemble reality. Traditional and logical ways of placing, representing, and interacting with objects are tossed aside in favor of seemingly random set of components instead.

Abstract virtual reality experiences open the users mind and allow them to see a completely different reality. I believe there is a lot to learn when experimenting with abstraction in VR and that the virtual world we live in the future will more closely resemble something out of Jackson Pollock painting more than anything around you right now. Another benefit to abstract experiences in VR is that there is no standard, so a singular developer like myself can produce something of meaning rather easily, since you no longer have to recreate systems from the real world. The game I looking to develop with this research may involve abstract components, but in general I will be looking more to simple graphics.

Survey Results

I have conducted a survey with 28 active virtual reality users in order to determine what other users and developers thing about realistic vs. simple graphics in VR. For the most part users prefered realistic graphics when using current-gen VR, contrary to what I believed.

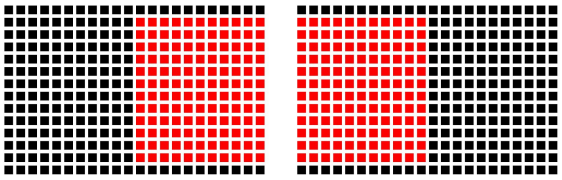


1.Simple (5.9%) 2. Medium (38.2%) 3. Realistic (55.9%)

I still believe simple graphics are the way to go when developing for current gen VR as it allows the developer to adapt to a wide range of upcoming headsets. I will expand on this in the following sections.

Next Gen PC VR

Second generation virtual reality hardware is right on the horizon, with most of the main players in the VR game planning a next headset (HTC, Facebook, Microsoft). This is important to consider as any experience you create in the next few years will surely be played on these next gen headsets. This means that many of the rules we are creating for developing on current gen VR will have to be modified slightly. This is normal with most video game development, some game developers needing to plan for next gen releases, but with VR the change is more drastic and less predictable. This is why the combination of simplicity and detail is very important, as it can allow you to have a game that can look good now, but still benefit from the increase of resolution and field of view coming in the next generation headsets. One soon to be released headset, the Pimax, is a good place to look for next gen VR specs. The headset features a substantial increase in both resolution and FOV, bringing the resolution up by 4 times (1080p per eye vs. 4k per eye) and the FOV by almost double (110 degrees vs. 200 degrees).



Red: Current Gen VR Resolution and FOV (Oculus Rift)
Black: Next Gen VR Resolution and FOV (Pimax 8k)

When asked whether a headset with a higher resolution and field of view would change their answer, many leaned even further towards realistic graphics. This was expected as the only reason we shouldn't use realistic graphics is because of the lacking of those two specs. *(See answers to question 5 in survey)*

Mobile 6 DoF

Something that is very interesting (and difficult) about virtual reality hardware development is that it is moving in two directions. The first was talked about previously, being the "Next Gen PC VR", and the other being Mobile 6 DoF headsets. Mobile 6 DoF includes a posionally tracked headset and controllers, allowing users to move like they do when using PC VR, but without a PC. 6 DoF stands for 6 Degrees of Freedom, allowing users to rotate in 3 axis as well as move

in 3 axis. The entire computer is contained inside the VR headset. This comes at a cost, which is what brings me to graphics. The processor inside the upcoming Mobile 6 DoF headsets, like the Oculus Quest, is the Snapdragon 835. This is the same processor we find in some smartphones like the Samsung S8. You are probably questioning the ability of a smartphone processor to drive the same experience you can get out of a PC VR headset, and you should. The Oculus Quest for instance runs at only 72 FPS, compared to the Oculus Rift's 90 FPS, but the differences don't stop there. John Carmack has compared the power of the oculus quest to that of an Xbox 360 or PS3, so the games should look as good, right? Wrong. The Quest has the same power but that does not mean it has the same quality of graphics. Most Xbox 360 games ran at around 30 FPS at near 720p resolution, compare this to the Quest which has to run at 72 FPS and at around 1440p resolution for each eye and you realize the quality is going to drop drastically. This is why simple graphics are again a very good choice when developing graphics for current gen VR, as it will not be as difficult to get them running on these processors.

Equation for how much worse the graphics will appear on oculus quest:

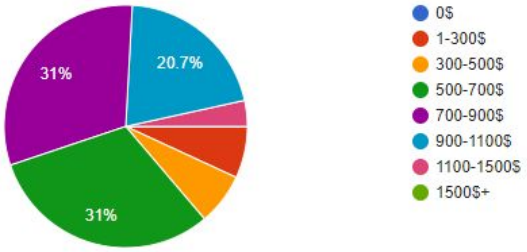
Pixels: 720p x 4 = **1440p**
Frame Rate: 30fps x 2.4 = **72fps**
Total: 4+2.4 = **6.4**

Therefore the oculus quest requires 6.4 times the processing power to achieve the same graphical quality as an Xbox 360. Now considering they are have the same processing power we can say that games on the Oculus Quest will look 6.4 times worse than on Xbox 360. So basically you are ending up with something that looks like a Nintendo 64 game. This is not necessarily a bad thing, like I said before games like Super Mario 64 still hold up today both in graphics and gameplay. It's simply a matter of putting as much work as you would into realistic graphics, into simple ones.

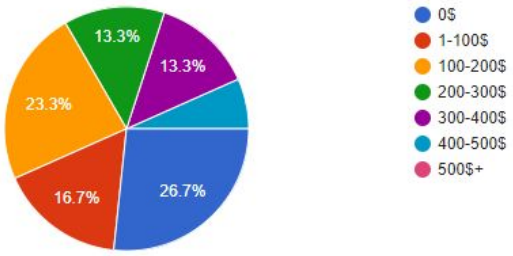
When asked whether they would prefer simple graphics on a mobile VR setup most users admitted that simple stylized graphics will work a lot better. (See question 4 in survey)

Price Survey

In the survey I conducted there was a small section questioning the users on how much they would pay for either of these upcoming VR headsets (PC VR and Mobile 6DoF).



Price users are willing to pay for next gen PC VR



Price users are willing to pay for Moblie 6 DoF VR

While this is not directly related to graphics it shows that the users currently using VR are more willing to pay for PC VR than they are for mobile VR. Over a quarter of the answers said they would not even pay 1$ for mobile VR!

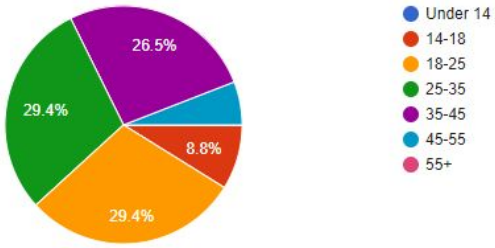
Going Forward

Due to a large list of reasons and factors, I will continue to develop my game with simple graphics. The main factor is that I plan to release my game on the upcoming Oculus Quest, where

realistic graphics are impossible. Due to the answers in the survey I may keep in mind the option of increasing the graphical quality of the game for a next gen PC VR release. If we use a combination of what game developers have learned about graphics over the past 4 decades, we can properly form an effective and beautiful graphical system for use in countless VR titles.

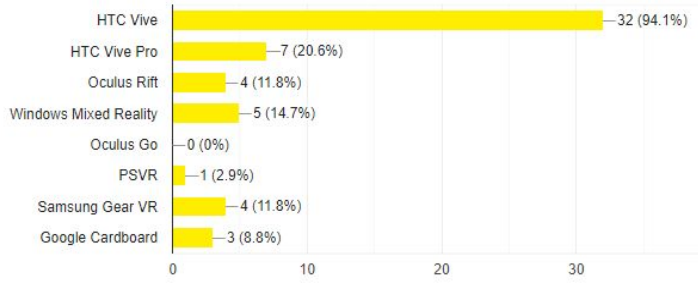
Methodology and Bibliography

The survey conducted for my research took place over 2 weeks and included 28 participants. The survey was given to members of various VR Facebook groups and was conducted using Google Forms. The VR users that took the survey were between the ages of 14 and 55.



Ages of VR users in survey.

The participants mostly owned standard current gen PC VR, like the HTC Vive.



Owned Headsets for Participants.

Link to Survey:

https://docs.google.com/forms/d/e/1FAIpQLSdydvb-poIveWc8ZIWS1H8quGiheXYyWTDB35FGrshQ5pzowg/viewform?usp=sf_link

Referenced Games:

Echo VR: https://www.oculus.com/echo-vr/
Rec Room: https://www.againstgrav.com/rec-room/
Climbey: https://arcadiavr.ca/product/climbey/

Online Resources:

https://www.nvidia.com/en-us/design-visualization/technologies/holodeck/

https://www.fastcompany.com/3058756/why-virtual-reality-will-change-design-forever

https://www.coursera.org/lecture/introduction-virtual-reality/realism-graphics-rMiMF

More VR Research and Demos:

https://www.jackh.ca/research-in-virtual-reality