Research in Virtual Reality

Physics

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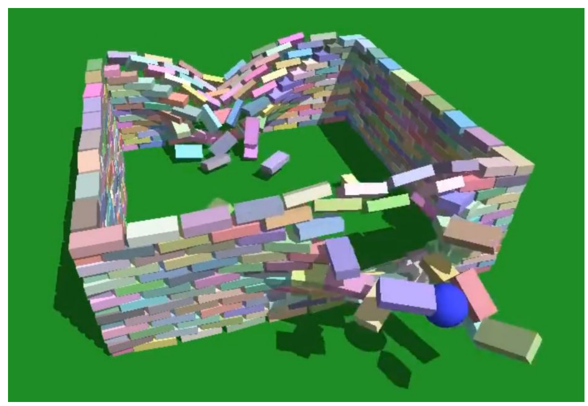
Summary

The following paper will be a short exploration of physics simulations in video games, specifically their place in the future of Virtual Reality games and experiences. In video games real time physics simulations are quite rare and this is due to the way that processors handle the math involved in calculating and rendering them. Your computer's graphics processing unit is it's main way of calculating and handling these simulations, but when it comes to certain real-time physics simulations only NVIDIA GPU's will work. This is because they have a special kind of core called a *CUDA core*. These cores were designed with rendering in mind and not only do they help speed up traditional 3D rendering, they also allow for some very impressive real time rendering techniques, such as physics simulations. The other make of GPU's are AMD cards and while they can handle simple physics simulations like rigid bodies, the rest of the simulations are near impossible for the cards to render at a reasonable FPS even for traditional 3D video games. When it comes to VR games we must again consider the added computing power needed. This is a problem as real time physics simulations are already extremely tough to calculate, so when you stack this on top of VR your options become very limited. This is why this paper will frequently look forward into the future of computers and VR to show these simulations true potential.

In the following sections we will look at all of the possible simulations, what they could be used for in VR and why it matters that we change the way we use them in VR.

Rigid Body

Rigid body simulations involve one or more 'hard' objects that react with each other based on real physical parameters like mass, scale, and gravity. An example of a rigid body interaction in real life would be something like a brick falling and landing on a sidewalk. This kind of simulation is rather easy to calculate and is possible using CPUs, AMD GPUs, and NVIDIA GPUs, while still maintaining a usable FPS. In VR these kinds of interactions are very common and are featured in almost every game. What makes these simulations work so well in VR is that unlike traditional video games, you can reach down on the ground and pick up the object, just like in real life. You can even throw the object at other objects and if they have rigid body simulations enabled they will react to that object hitting them! It really is an amazing feeling in VR and one that you really cannot get with regular video games. Virtual Reality has the ability to strongly immerse users, but it's important to not stop at the hardware and to make sure that the software too immerses the user. We can achieve this by using physics simulations that replicate our own universe's laws of physics.



Still from Rigid Body Simulation

Taxing Simulations

Unlike Rigid body simulations, some real time physics systems require very intense computing power. These kinds of simulations are only possible on NVIDIA chips and barely even at that. These include the following 4 simulations: *Soft Body, Rope, Cloth,* and *Fluid*. When we weigh the computing power with the computing power required to drive VR, we conclude that you must limit these simulations to one very small portion of the game.

Soft Body

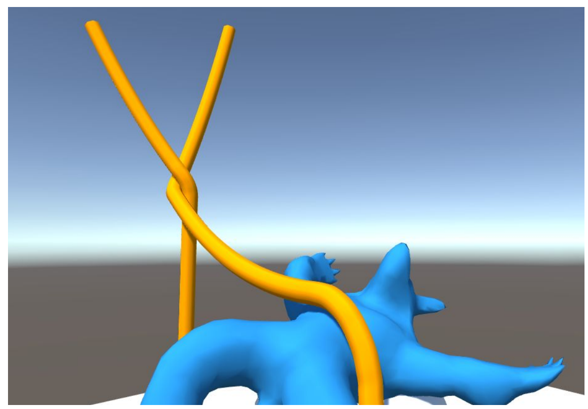
Soft body simulations are similar to rigid body simulations in that they can applied to any type of object, but in this case, when the object interacts with another it acts more like a water balloon, slightly deforming as it collides. You can also modify how much the object deforms, at its hardest it is exactly the same as a rigid body, and at its softest it will completely collapse and deform to whatever shape it interacts with (if it were to fall on the floor it would become completely flat and shapeless). The types of objects we would use these simulations for are rare and so we don't see them in games too often. Interactions for these kinds of objects in VR would work similar to rigid body, in that you can pick up the object and toss it around. Ideally you would also be able to grab the object with your other hand and stretch and pull it at will.

Still from Soft Body Simulation

Rope

Rope simulations are just as they sound, a simulation of a rope, string, or chain. These simulations work by connecting a series of points with soft bodies, giving the impression of a real rope. There are limitations to these simulations that make it impossible to do certain things you can do with real ropes, such as tying knots.

In VR, rope simulations could make a huge impact if used for something like a grappling hook, needing you to actually throw the rope correctly to hook a ledge. Because the simulation is all dynamic and real time you could use the rope for other uses too, like taking down enemies or grabbing items. This kind of interaction works really well with VRs intuitive control and movement system. You want to throw that brick? Pick it up and throw it! You want to climb a wall? Throw your rope up and get climbing! Its these kinds of physics based systems integrated with virtual reality that will separate games from true "virtual realities", more on that later.

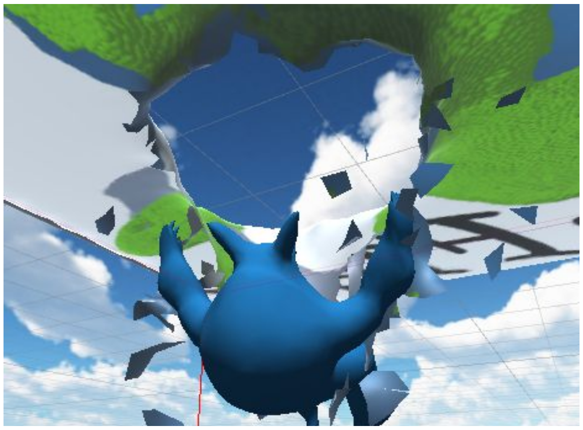


Still from Rope Simulation

Cloth

Cloth simulations involve applying rigid body simulations to vertices on a plane object and then estimating the space in between them, and then smoothing those spaces into a cloth like surface. These are used in some popular games in both traditional games and virtual reality games, like in *Red Dead Redemption 2* when you enter the bathroom in Valentine, or in *Marvel Heroes United* where certain character's (Storm, Doctor Strange) costumes hang off and move as you move your arms, just like in real life. The uses are obvious for these dynamic simulations, basically anywhere you would have cloth, like your clothes or a flag. There are also cloth simulations that allow you to tear and rip them, leaving small pieces scattered around.

This furthers the realism allowing you to have strong cloth materials and weak cloth materials.



Rigid body falling through tearable cloth

Fluid

Fluid simulations are probably the most difficult to render due to how they work. They are simulated by essentially generating a huge number of small slippery rigid bodies. These then blend together using rendering tricks and result in something that resembles an actual liquid. These simulations are often avoided in traditional video games due to their difficult computation, and also because game designers have developed workarounds that look great and keep performance at an acceptable level.

In VR however its more difficult to simulate water, as you interact with things on a much intimate level. If you were to pick up a cup of water in a traditional video game (first of all your character has to be able to pick it up) then you would only be able to do with it what the game developers intended. If you were to pick up a cup of water in VR you would be able to do anything with just because it's VR, you can drink from it, throw it at the wall, or turn it over, and if you did you would expect the water to drain out onto the floor, if it doesn't it breaks immersion. Because of the range of movement and interaction given by VR, game components in VR games must also have a wide range of movement and interaction.

Liquid simulation from NVIDIA VR tech demo

Complete Simulation

What this paper is getting at is that ideally, every single object in a VR world would be linked with some kind of physics simulation. Rigid body, soft body, cloth, rope, and fluid simulations should be included at every possible opportunity. This would result in a world that really *feels* real and that compliments the potential of virtual reality. I call this the "Complete Simulation" as it is getting close to a completely accurate simulation of our real physical world. This doesn't mean it has to have the same physical attributes as earth, but has to follow the same physic rules set in place by the universe since the big bang. This means you can have games with altered gravity, and it can still feel realistic, as long as you apply that altered gravity to all of your simulations.

When

The Complete Simulation is still a very *very* far ways away. Even the very top tier consumer NVIDIA graphics cards can only render a handful of these simulations at once at that's non-VR. For example *Arkham Knight* has a short list of simulations including smoke, soft body, and rain. We need GPUs to get at least 2 times more powerful to get to even this level in VR so don't expect the Complete Simulation to be available computationally for a long time, but at the rate computers develop it is not out the questions to expect it within our lifetimes.

Dynamic simulated Smoke from Arkham Knight (2015)

This is a problem because VR hardware developers are also trying to make the headsets smaller, and more mobile, sacrificing computation power. This could delay the Complete Simulation by decades, or at least limit the future VR developers from using these simulations in their games. Hopefully we see something along these lines at a location specific VR venue, like an art gallery or arcade.

Going Forward

For the game I am created next semester I will be omitting most of these physical simulations as I am wanting to be able to port the game over to Oculus Quest, the upcoming mobile (and therefor weak computationally) VR head mounted display. I will however use the most versatile and easy to handle simulation; rigid bodies, like there is no tomorrow!

I will, however, keep in mind the dream of the Complete Simulation and will continue to experiment with dynamic physics simulations in many of my upcoming PC based projects and games. For now I have a short VR physics demo available for download below where you can experience what we can do with these simulations today.

Bibliography

NVIDIA FleX (in game physics simulations for Unity) : https://developer.nvidia.com/flex

NVIDIA Fun House (VR physics simulation demo) : https://www.geforce.com/games-applications/pc-games/nvidia-vr-funhouse

Collection of research papers and demos by Jack: https://www.jackh.ca/research-in-virtual-reality