3D FLUID FLOW SIMULATION FOR EDUCATION

Team 73

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Abstract— **This project will provide the user an interactive experience with a 3-D fluid simulation in virtual reality (VR). The goal of the project is to make learning fluid mechanics an interesting experience and that teachers will be able to use it in their classrooms or encourage k12 students to choose Science Engineering Technology and Mathematics field. The team will use the game engine Unity to complete this interactive experience with fluid flow. Two applications have been created. Firstly, biological flow simulation data from Lattice Boltzmann method (LBM) was utilized to make an animation with cancer cells moving with a stream of red blood cells. The cells were generated in Paraview using LBM data to create these Unity object models and their placements in the bloodstream. Second, the team also utilized the Smooth Particle Hydrodynamics (SPH) from an open source code to create an interactive fluid flow simulation within Unity by Leonardo Montes. The user can use a mouse to move a control object to interact with fluid particles in Unity. The user will also be able to move the SPH particles with the arrow keys. In addition, the user can examine detailed flow physics such as how each particle of the fluid interacts with each other. The interactive program was implemented with C# script in Unity to make the simulation as real world as possible.**

I. INTRODUCTION

Fluid Mechanics is the basis for the entire project and is essential in mechanical engineering as well as other engineering disciplines that deal with physical systems. Its application can be found from irrigation canals to toy water guns. Many of today's greatest technological advancements would not be possible without fluid mechanics. Understanding fluid mechanics has been enhanced in modern times using computer systems. Furthermore, virtual reality technology combined with fast computational processors is allowing us more than ever to simulate fluid behavior in real-time with an immersed environment.

The use of a game system and a virtual reality headset will give a broader perspective on what the project could be to peak interest in STEM fields by allowing children to use the simulation. The link between a game and learning is a powerful tool because it helps engage students with the material they are learning. Unity was chosen for this very purpose so that students can possibly learn a very difficult subject. A game will get more attention and interaction from a student than the traditional form of a classroom lecture and textbook. The visualization via the virtual reality also enforces what amazing experience the STEM field can create and helps give different perspectives on the flow of fluids and how individual particles interact.

II. DESIGN FEATURES

A. SPH Particle movement with arrow keys

The team was able to make a selected particle in the simulation to move according to a exerted force. For example, in order to move a particle in the direction of the z-axis, there would have to be a force vector with just a force vector with a z-component. The implementation is done using the *Vector3* function in Unity. The engineering group decided on a base acceleration constant of 9.81 to imitate a similar force when gravity is acting on the particles when it is free falling. Next, the acceleration vector must be multiplied by the density and a scaling factor set by the user for the particles to be pushed off each other. The density allows this particles to actually have an interactive force between the particles and the scaling factor on the force vector allows the user to get different interactions; such as moving the particle by a small amount or a large amount when pressing the arrow keys. Afterwards, this force will be applied to the particles game object array through the *forcephysics* vector. A simple if statement was used to determine if users press down the arrow keys so that a designated force is added to the particle to move it.

B. Object interactions with mouse in SPH simulation

The team used the SPH algorithm to create the interactive flow simulation. In Unity, a control object was introduced with a tag **SPH Collider,** as shown below.
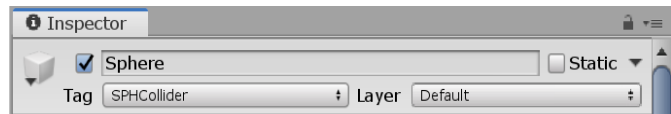

Figure 1: Apply a tag to the control object in Unity

The simulation detects any collisions that happen between any object with the **SPH Collider** tag and any SPH particles. Through the collider tag, any object that not belongs to SPH particles can interact with each other and with SPH particles. With the same tag, any Unity object that is made outside of the simulation becomes a part of the simulation. Therefore, an item like a sphere created outside SPH particle group was made to collide with the SPH particles. The item has a script where the user can control and drag it around the world with the use of a mouse. This can spark interest within

students because they do not simply look at the simulation animation but they can interact with simulation as well.

C. Simulation Video with red blood cells and cancer cells

Additionally, the team constructed a simulation that includes moving cells within a flow. Using cell data generated by Paraview, a 3D Data Visualization software, we were able to convert these cells into Unity objects, i.e. Each of the cells was converted to a .obj file which stored the coordinates for the cell. Taking time sequential data for the cells and essentially playing them one after another the team was able to see how the cells moved in real time.

III. RESULTS

In Fig. 2, the team mimicked a simulation done by Dr. Tan and his research group. This was done for an educational purpose in order to show precollege students how cancer cells moving in a microfluidic filter. This can also be linked with a virtual reality headset to see how blood cells move in a 3D environment.
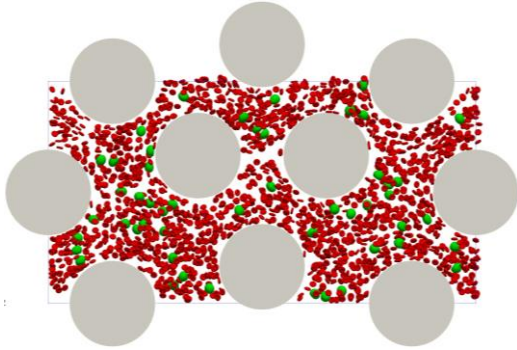

Figure 2:Visualization of simulation results of cancer cells (green) moving with red blood cells in a microfluidic channel with cylindrical posts.

The team also created a working fluid simulation that the user can interact with using a mouse, as shown in Fig. 3, and arrow keys, as shown in Fig. 4. The gray sphere is not part of the SPH particles. We successfully collided the gray sphere with the SPH particles (blue). Fig. 3 shows that the gray sphere can impact the SPH particles and break the SPH particle cluster apart.
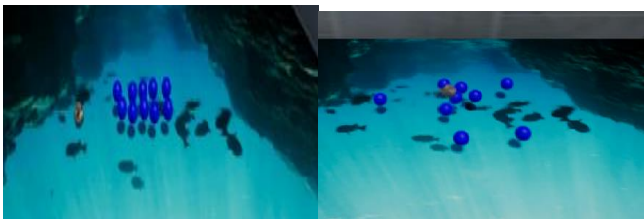

Figure 3:A gray sphere controled by mouse impacted SPH paticles and break the SPH particles apart.

Fig. 4 showed another example where a force vector was added to move the sphere along a specified direction. The particle was moved up in the Y-axis(In Unity Y-axis is your vertical axis in 3-D). This adds another layer of interactivity for the user to be able to do with the SPH simulation.
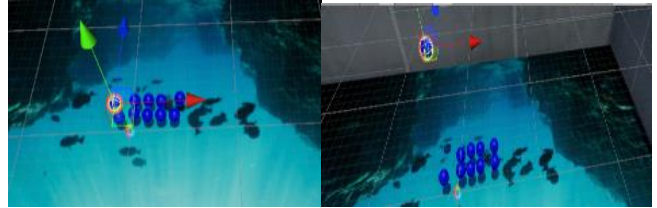

Figure 4: Arrow keys were used to control force magnitude exerted on a target sphere colliding with SPH particles.

IV. Conclusion

The main objective of this project is to inspire children to go into the STEM field by showing them a visualization of complicated flow simulation. Unity provided the versatlity needed to complete both goals of the project. Unity helped make an interactive experience that any student will find engaging. The use of SPH method helped create various real time fluid simulations. Our team was able to make the user move a sphere outside the simulation and have it interact with SPH particles using the mouse. Unity also helped with movements with the SPH particles themselves with the use of the arrow keys. These interactions help steer away from the the regular classroom and book format to a more interactive experience in learning fluid mechanics. Unity and its compatiblilty with virtual reality also gave another way to visualize data such as shown in Fig. 2. The virtual reality headset offers different persepectives of the blood flow, giving the user a different range of visualization angles and different locations in an immersed enviroment. Unity showed that it was the best way to create a more imersive learning experience with fluid mechanics.

REFERENCES

[1] Montes,Leonardo(2019)Unity ECS Job System SPH(Version 2.0)[C#].https://github.com/leonardo-montes/Unity-ECS-Job-System-SPH