Interactive Cinematic Scientific Visualization in Unity

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1 INTRODUCTION

Cinematic scientific visualizations turn complex scientific phenomena and concepts into stunning graphics and make them easier for the general public to comprehend. Adding interactivity to cinematic scientific visualizations is highly beneficial especially for educational purposes, as it keeps the viewers engaged and promotes active learning [Cano et al. 2017]. Although there are existing software tools such as VisIt that are capable of handling large data sets and allow for interactive exploration, they are usually designed for scientists and not meant for producing cinematic visualizations for the general public. Creating aesthetically pleasing visualizations of scientific data helps to better communicate the scientific concepts, increase impact, and reach a broader audience [Borkiewicz et al. 2018]. As existing examples of visualizations that are both interactive and cinematic have mainly been produced with custom software, there is a lack of easily accessible tools for developing this type of scientific visualization.

Game engines have been gaining popularity in fields outside of the video game industry primarily because they provide a feature-rich development environment for real-time applications with high-end graphics needs. As game engines are designed to efficiently manage resources, produce high quality graphics, and handle user input, we believe that they have the potential to serve as a good tool for developing interactive cinematic scientific visualizations.

2 OUR APPROACH

To research the feasibility and value of using game engines to create interactive cinematic visualizations, we experimented with subsampled scientific particle data in Unity as a proof of concept. We chose to work with particle data because it is a very common data format in the field of physical sciences, and we decided to use Unity because it has a powerful built-in particle system and is known for having a user-friendly interface.

We went through three stages of research:

(1) Testing the performance of and experimenting with Unity's particle system using large datasets
(2) Developing an interactive cinematic visualization of a scientific model of moon formation
(3) Studying the effects of our visualization on young viewers

3 BENCHMARKING AND OPTIMIZATION

A typical scientific particle dataset obtained through simulation includes particle position and additional attributes at each timestep. To visualize particles in real time at 24 FPS using Unity's particle system, we would need to update the particles with particle data within 41 milliseconds in each frame. In this stage, we benchmarked the file reading and particle update time to find the maximum number of particles we could afford to visualize. We first compared two file reading methods — binary and string, and we found that the binary method performed approximately 100 times faster than the string method. Next, we recorded the amount of time it would take to update various numbers of particles with a timestep of scientific particle data. We found a linear relationship between the particle update time and the number of particles. Updating particle color in addition to position nearly doubled the update time.

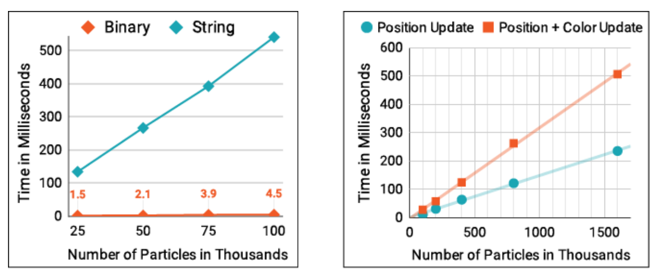

Figure 1: Results from performance testing of data reading methods (left) and particle updates (right).

As assigning the positions of the particles with particle data at every frame proved to be costly, we decided to make use of the particle system's ability to approximate physics to reduce the frequency of particle updates with particle data. We assigned both the particle position data and velocity data to the particles in the particle system every set number of frames, thereby letting the particle system interpolate the positions of the particles for the in-between frames. As an experiment, we fixed the number of particles to 300 thousand and recorded the average FPS for varying particle update frequencies. While we saw a performance improvement with decreased particle update frequency, this optimization technique is a trade-off between performance and accuracy.

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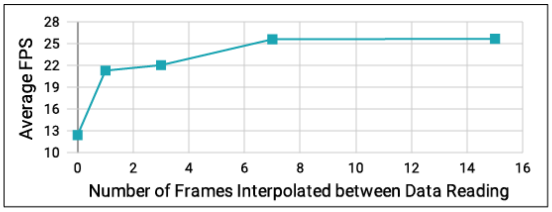

Figure 2: Results from increasing the number of frames interpolated by the particle system using particle velocities between particle updates with particle data.

4 VISUALIZING THE MOON FORMATION

To investigate the process of developing interactive cinematic visualizations in a game engine, we created a visualization of the moon formation. The original dataset was produced by Dr. Robin Canup of the Southwest Research Institute and consisted of 3676 timesteps of 1.17 million particles that each had 14 attributes [Canup 2012].

Based on the findings in the previous stage, we made the following adjustments to achieve a smooth frame rate:

- Every 6th particle in the dataset was sampled, yielding approximately 200 thousand particles
- Only the position, velocity, density, temperature, and size attributes of the particles were used
- The particle data was converted to shorts from floats and stored in binary format to reduce file size and reading time
- The color, transparency, and size of the particles were updated only when the change in value exceeded a threshold
- The particles were updated with real timestep data only every 4th frame while the particle system interpolated the positions using particle velocity for the in-between frames

To create a realistic and cinematic representation of the particles, we set the color and transparency of the particles based on their temperature and density values. We accounted for the downsampling of the particles by setting the size of the particles to their original size multiplied by a factor. To allow viewers to observe the changes in specific attributes of the particles, we designed multiple views with different colorations for individual attributes.

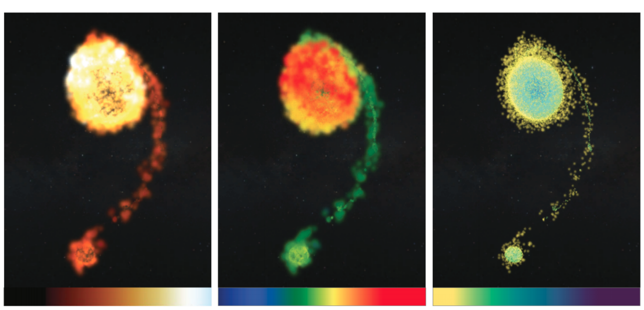

Figure 3: From left to right: the realistic view, temperature view, and density view of a snapshot of the visualization along with their corresponding color maps.

We added interactivity to the visualization by implementing three-button mouse controls for scene navigation and standard video playback controls using Unity's built-in UI and event-listening systems. Viewers could also toggle between the realistic, temperature, and density views of the particles.

Our 200k-particle visualization plays at 24 FPS on our PC with i7-3770 3.40GHz CPU, 24 GB RAM, and 2GB NVIDIA GTX 960.

5 STUDYING EFFECTS OF INTERACTIVITY

We conducted a survey study to evaluate the interactive features of our visualization of the moon formation as well as to study the effects of interactivity in visualizations on young viewers. In this pilot study, we recruited participants of ages 8-18 and randomly assigned them to either the experimental group, which would view the interactive visualization that we developed in the previous stage of our research, or the control group, which would view a non-interactive video-style version of the same visualization. After viewing the visualization, each participant was asked to answer how much they agreed with statements in a survey that pertained to their confidence about their understanding of the scientific phenomenon, their interest in earth and space science, and their enjoyment of the visualization. We then compared the responses of the two groups.

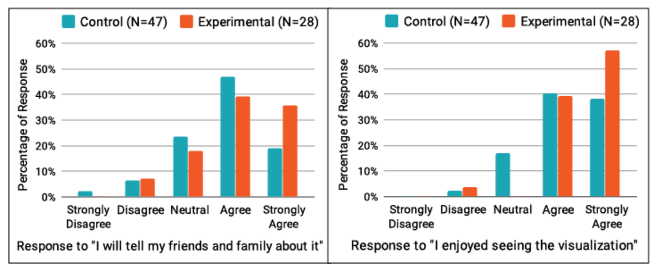

Figure 4: The two groups' responses to two survey questions that pertained to their enjoyment of the visualization.

We observed a difference between the groups in their enjoyment of the visualization. The experimental group enjoyed the interactive visualization more than the control group enjoyed the non-interactive version. Enjoyment plays a big role in children's learning experiences because a high level of enjoyment is linked to higher engagement during the learning process as well as increased interest and motivation [Hernik and Jaworska 2018]. As our results showed that adding interactivity increased our participants' enjoyment of the visualization, and game engines are well-established for developing interactive applications, our finding suggests that there is value in developing interactive cinematic scientific visualizations in a game engine for educational purposes.

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