GraViz - An Interactive Visualization of Gravitational Waves

Stefan Lonschar, Christian Eckhardt, Krzysztof Pietroszek

Graz University of Technology, California Polytechnic State University*, University of America Washington D.C.

Project Summary

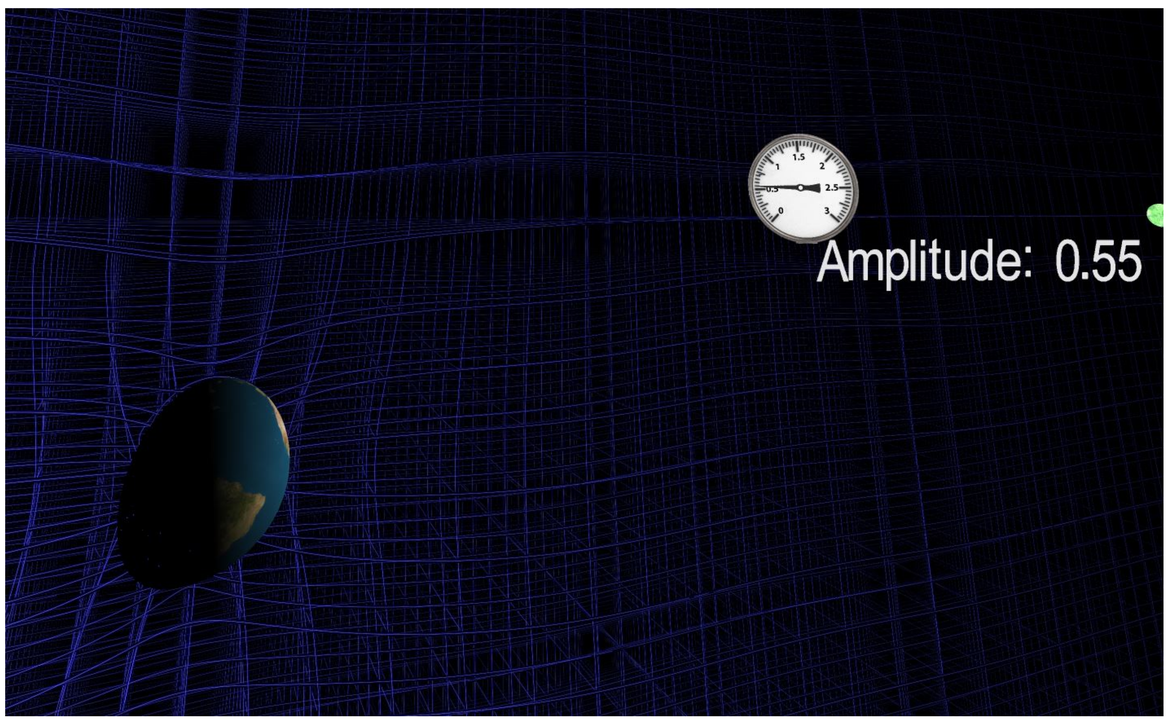
In this project we created a novel interactive virtual reality learning environment to improve the understanding of gravitational waves and their effect. A user sees a field density representation of the waves traveling through space time, as well as an abstract representation of earth with an orbiting moon under their effect. The user can travel through this environment via VR controlelrs and has a display with information about the waves effect at one specific point. With the VR environment and corresponding pre and post experience questions we could already show an improvement in understanding on a small set of participants. The following analysis discusses the project's current state and ideas that can motivate the further development of GraViz.

As it has been phrased in other places: with Ligos discovery of gravitational waves we found another sense for analysing the galactic history and it's developments in former unknown distances, but first we need to learn how to use this new perception of information .

Content

This project has a solid and comprehensive purpose, and its goals are met by its capabilities. The objective behind this project is to offer an accessible way for astrophysics students and non physics experts alike into understanding this new way of seeing our universe.
Where GraViz really stands out in comparison to classic two dimensional representations of this relatively new discovery is by the added depth impression and interactivity, which leads to greatly increasing the immersive effect and with that the understanding of a user.

Study participants are given a fully visual representation of gravitational waves and it's effects in an intuitive way that can be give deeper insights to anyone with very little prior knowledge and just a short introduction. The user can freely move in the scene and also change attributes of the waves source in order to get a more in depth understanding.



Methodology

The gravitational force is a vector field and as such consisting of a weighted vector for every point in space. Early testing showed, that the presentation of a regular vector grid in VR is overly complex and hard to get immersed into. Other attempts with color coding the strength of the gravitational force in addition to the directional vector showed similar weak results. To illustrate the gravitational waves, we rather decided to use a density grid: Regular points in space, which are connected in x, y and z-direction and are warped due to gravitational forces.
Additionally we added a representation of earth with an orbiting moon that also show their respective gravitational effect on the density field. These are especially meant to give the user objects he can relate to in order to improve the understanding of the overall scene.
Due to the extended GPU shader work, we used OpenGL for the graphics API and OpenVR as VR library. Our environment is based on a Windows PC with an AMD Ryzen 7, an NVidia GTX Titan V graphic card and HTC Vive Pro Eye as our HMD.

Test Setup

We identified three main areas of understanding gravitational waves such as wave source, spatial irradiation distribution and wave type, which the VLE supports and was designed for. Therefore the study participants were given following main questions before and after experiencing the project environment.

Research Questions:
1. What kind of wave did you observe?
2. What is the effect of changing the period-time and/or the radius of the binary star system on the wave amplitude?
3. Where in the observable scene is affected the most by the waves?

After evaluating the users previous knowledge in a short pre questionnaire, he/she was given the opportunity to explore the scene by himself with the background task to identify the content of our research questions. After experiencing the scene a post questionnaire was used to show gained insights.
As it is not feasible to ask non physics experts to spend hours to learn the theoretical background on gravitational waves for understanding we decided that our simplified research questions are a good first indicator for the practicability of our approach.

Intermediate Results

As seen in table 1 all participants were able to get a deeper understanding of our initial research questions compared to their previous knowledge on the topic. Despite the small number of test subjects we could already clearly identify a deeper comprehension of the cause and effect of the defining factors of a binary star system. After observing the simulation every participant was able to figure out the influence of the factors distance and period time on the emitted gravitational waves. Although it was not absolutely clear for everyone to observe the wave type, everyone figured out the dependency of amplitude and frequency of the waves to rotation speed and radius of the star system and claimed one form or another of a function of torque to influence the wave attributes. We observed that especially the imagined area of maximum effect was not intuitive for most participants and got clarified without exception after observing the simulation. Another point that almost all participants had in common was the misunderstanding that gravitational waves would get stronger if the binary system would have a lower distance between the stars, which also got cleared up after observing the simulation.

Further Project Plan

At its current state, the project is only giving the user the ability to move in the scene himself and adjust the gravitational waves source attributes to change the waves behaviour, however it already sets up the framework for a wider scope of functionality. These will include the ability to interact with all objects in the scene like the earth and moon and a better interface for further understanding. It is important to note that in future work further investigation with no less than 50 participants will be carried out to confirm our initial results.

References