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Immersive 3D Visualization of Astronomical Data

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Abstract. The immersive-3D visualization, or Virtual Reality in our study, was previously dedicated to specific uses (research, flight simulators, etc.) The investment in infrastructure and its cost was reserved to large laboratories or companies. Lately we saw the development of immersive-3D masks intended for wide distribution, for example the Oculus Rift and the Sony Morpheus projects. The usual reaction is to say that these tools are primarily intended for games since it is easy to imagine a player in a virtual environment and the added value to conventional 2D screens. Yet it is likely that there are many applications in the professional field if these tools are becoming common.

Introducing this technology into existing applications or new developments makes sense only if interest is properly evaluated. The use in Astronomy is clear for education, it is easy to imagine mobile and light planetariums or to reproduce poorly accessible environments (e.g., large instruments). In contrast, in the field of professional astronomy the use is probably less obvious and it requires to conduct studies to determine the most appropriate ones and to assess the contributions compared to the other display modes.

1. Introduction

We began our work by looking for interesting use cases. We used the first version of the SDK Oculus Rift to achieve the first prototypes to gain the necessary experience with such tools. We have developed both with a framework, Unity in C#, with the Irrlicht 3D engine in C++ and directly with the Oculus libraries in C++ (OpenGL skills needed). This allowed us to assess the benefits in development time with frameworks but also to measure their limitations. As it was something completely different from our other developements, it was necessary to start with a study to select a few use cases and to answer a few questions: which audience?, which kind of data ?, which application?, how to use the Oculus ?, etc. It had to provide a benefit compared to a 2D or a 3D visualization on a 2D screen. To learn how the Oculus Rift works you can refer to <http://www.oculus.com/>. We also conducted a development around SkyBot3D

(Berthier et al. 2006), a tool to explore the Solar System in 3D. We will explain how we have proceeded. We will present a review of this work both in terms of results and human investment in the project. This work is ongoing in the frame of our R&D actions (Schaaff et al. 2014).

2. Which audience ?

The expectations and the constraints are not the same for general public or education, and astronomers. In the first case, the immersive experience is already fun by itself with pretty images, it is not mandatory to respect scales, it is easy to find a compromise between performance and features, and at least it is a way to learn with fun. In the second case it must be relevant and bring an added value compared to another 2D/3D visualizations, the performances must fit with the needs (volume of data for example). It is better to find the right use cases and to focus on them. Our experiments dealt with both the two cases.

3. Which kind of data ?

In the professional field, visualization of data cubes (Fig. 1) appeared to us as an ideal candidate. The idea was to study what the navigation in this datasets could bring to the astronomers. The 2D visualization is poor, the 3D-like is better so what's the advantage for an immersive-3D? We worked with data cubes from High-resolution simulations of re-ionization of an Isolated Milky Way-M31 Galaxy Pair (Ocvirk et al. 2013). A 2D display hides a large part of the information; a 3D display (e.g., with Yorick) can bring a highlight of several details. Immersion in 3D with the ability to navigate in the cube offers new perspectives of interpretation. In the coming years the visualization of large datasets (volume and multi-dimensional) and the capacity to discover and understand from these datasets will be a real challenge (Donalek et al. 2014).

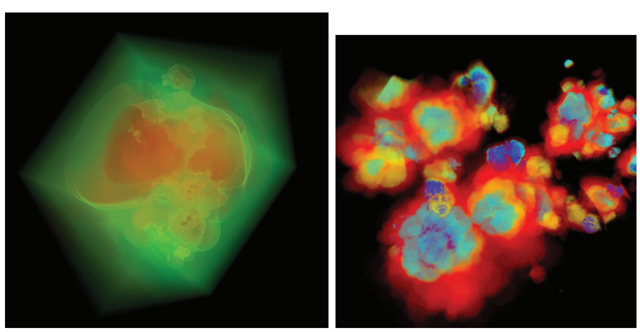

Figure 1. High-resolution Simulations of the Reionization of an Isolated Milky Way-M31 Galaxy Pair

4. Visualization of data cubes and performances

We have worked with 64^3 and 128^3 datacubes. In 2 to 3 years we should be confronted to 1024^3 and even 8192^3 for some parts of the simulation. And the multi-dimensional aspect (temperature, density, velocity vector, ionized fraction, etc.) will also become crucial.

The volume to visualize becomes quickly a bottleneck and it is necessary to find solutions to keep a smooth navigation in the data. A common solution is to divide it with the Octree method. The scene to visualize is put in a cube which is divided in eight cubes which are also divided in eight cubes, etc. (Fig. 2). With this approach it is not necessary to manage everything; it becomes possible to visualize only the cubes which are really visible.

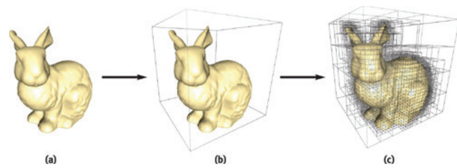

Figure 2. Octree principle (Credit: Wikipedia)

The Fig. 3 shows an example (a flat view and a view for the Oculus Rift) using the Octree method with a special rendering to show the cubes.

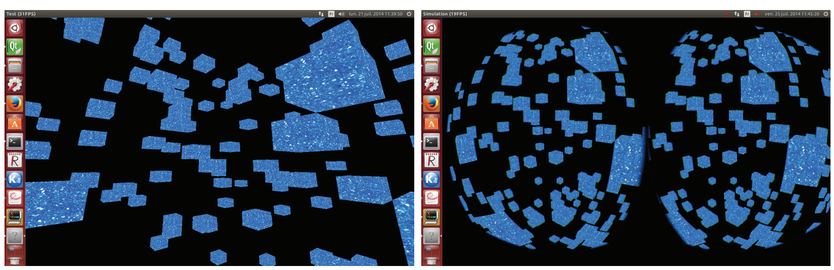

Figure 3. Simulation data visualization applying the Octree principle

5. Introducing the Oculus technology in existing applications

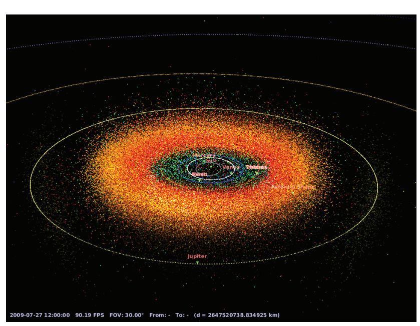

Figure 4. Skybot3D

An other side of our experiment was the introduction of the immersive-3D visualization in an existing application. The first step was to find the right application with a possible added-value. An application using OpenGL was a plus. Skybot3D (Fig. 4) is an extension of the SkyBot service which contains the ephemeris of all the known solar system objects (more than 630,000 in Apr. 2014). The high accuracy ephemeris provided by Skybot3D makes it perfect for scientists to get quickly a snapshot of the solar system at a given epoch. In this application the visualization is based on OpenGL. The immersive-3D visualization allows the user to navigate into the solar system as on-board a spacecraft, to learn the 3D structure of the small solar system objects, and to visualize the various population classes of asteroids (e.g., NEAs, Trojans, Centaurs, KBOs, etc.) and comets. It took about four weeks of developer's time to add support for the Oculus in Skybot3D.

6. Conclusion

As we have developed prototypes both with a framework (Unity) and directly in C++, we have a few remarks concerning the skills needed to work in this domain. With an integrated framework it is relatively easy to develop quickly a prototype but it is limited because it is not easy to use it for dynamic visualization of the data. It is difficult to model the simulation as it will evolve depending on several parameters (e.g., time). In the second case, it is necessary to learn how to use OpenGL because it is the heart of the immersive-3D visualization. It is possible to develop quickly simple visualizations for Education or for the outreach of a project with a framework. We are continuing to work on the improvement of the performances and the strategies to be able to manage larger cubes of data. Concerning the visualization of data for astronomers it seems that it is better to develop directly in C++ with the Oculus libraries and with good skills in OpenGL. It becomes then possible to implement methods (like the Octree) to improve the capacity of large dataset visualization. Another important point is the ability to enrich this display by adding information (text display, highlighting specific areas, etc.). In addition to these early developments, we are continuing the study on the potential contributions in other fields (HEALPix surveys (Górski et al. 2005), catalogues, etc.).

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