Four Virtual Reality Simulations for Teaching Earth Sciences

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Abstract

In a previous work we proposed a multidisciplinary methodology to produce interactive, virtual reality learning objects to be used in courses for Earth science undergraduate students. In this work we present four recent products from our Visual Laboratory for Earth Sciences at CCA, UNAM. This is a result of the contribution of computer science undergraduate students, computer graphics and visualization specialists and Earth scientists. We are using affordable modern technology, open source libraries and public domain data.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism —Virtual Reality

1. Introduction

In Siggraph 2009 [AS09] we proposed a multidisciplinary working methodology to produce interactive learning objects based on simulation and virtual reality to be used in introductory courses for Earth Science undergraduate students. We showed a way to make the production of such learning objects affordable and efficient, using modern technology, open source code and the integration of multidisciplinary, multilevel teams of faculty and students in our Visual Laboratory for Earth Sciences.

Modern technology helps to improve learning by allowing the students to interact with the simulations inside a virtual environment, understanding natural phenomena and addressing their own misconceptions through direct experience. In this work we present four recent simulations produced in our Visual Laboratory for Earth Sciences at CCA, UNAM. This is a result of the contribution of Computer Science undergraduate students, Computer Graphics specialists and Earth scientists. Although these simulations can actually be used in Earth Science introductory courses now, they may still be considered work in progress.

2. The simulations

The learning objects presented in this work are virtual reality simulations intended to provide the students with active experience with some basic concepts of Earth Science and seek to address some common misconceptions, in the same spirit as [BBCN*09].

These simulations run in affordable recent generation workstations with multicore CPUs and advanced GPU cards and high-definition stereo displays. They all run over open source graphics libraries, like the scene graph and basic interaction manager OpenSceneGraph (OSG), and real-time rendering is enhanced with OpenGL GLSL shaders. All the simulations use the same 3D navigation through OSG's camera manipulators. Most of the scientific data used in the simulations is in the public domain, from several sources.

2.1. The annual seasons (climate variability)

Some misconceptions about the cause of the annual seasons are still common among students, like the belief that the distance of the Earth to the Sun is the important factor, in spite of the fact that the Earth is closest to the Sun in January, when the Northern Hemisphere is in full Winter.

This simulation presents progressive views, starting from a simple plane rotating in front of a long distance source of light, showing how the incident radiation on the plane depends on the incident angle. Then the Earth is shown in a fixed position and the inclination of its axis oscillates, simulating the relative position of different zones on Earth during the year. The following view is a simulation of Earth's orbit around the Sun. The last view shows the relative trajectory of the Sun around a selectable position on Earth. In all the

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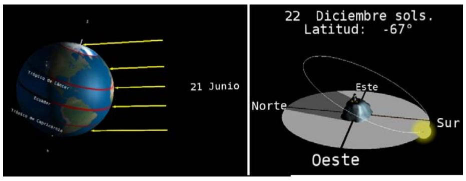

Figure 1: *Fixed, orbital and on Earth views of the annual seasons simulation.*

views the user can change the speed of the Earth's rotation and translation, and can select the season of the year and the time of day.

2.2. Plate Tectonics (Historic Geology)

Another elusive topic for first year students is plate tectonics and the geologic evolution of planet Earth. In this simulation, the face of Earth is shown from Pangea's time (300 million years ago) to the present and to the possible future evolution to *Pangea Ultima*, 250 million years in the future. The user can change the time arbitrarily or as an animation for a specific period. Particular plates can be highlighted, using GLSL shaders, to show for instance the movements of the plates that form the Mexican territory of today.

The Earth can be represented as a sphere or as a cylindrical projection. The continents can be shaded with schematic simple colors or using realistic textures. The ocean floor can be unhidden to show the tectonic boundaries, the oceanic ridges and the faults that evidence the tectonic movements. The simulation also includes a geometric view to illustrate Euler rotations.

Part of the data used in simulation is licensed from [Sco01].

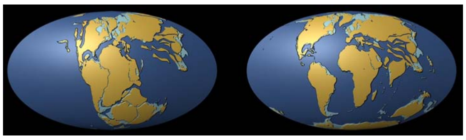

Figure 2: *Plate tectonics from Pangea to Cretaceous.*

2.3. Mexican terrain explorer

Using high resolution height fields and satellite images, we built a model of the Mexican territory which can be viewed from a space point of view as a spherical patch, to a view as near as a football field. As the camera is closer, the geometry and the textures are changed accordingly, following Level of Detail (LOD) techniques. Overflight views make evident important geological features like the volcanic belt, the trails of ancient glaciers from past glaciations, and the footprint of huge calderas that shaped mountain ridges like Sierra Madre Occidental.

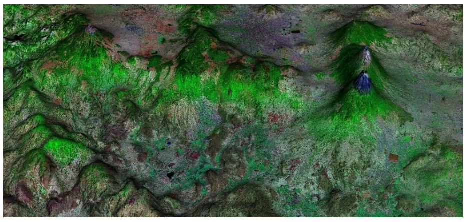

Figure 3: *Terrain explorer view.*

Any georeferenced 3D model can be accurately positioned over the terrain. Raster or vectorial geographical information data may also be rendered. In fact this simulation may be considered as a basic 3D Geographic Information System, and can be used to teach many topics over the Mexican territory, like the geology of the Mexican Volcanic Belt or the national orogeny.

2.4. Tide simulation

This is an interactive simulation of Earth's tidal system. It is progressive because it starts with a simple sphere, representing Earth without oceans. We add an external object (the Moon) and show the tidal forces using color cues and mesh deformation. Then we add a second external object (the Sun) and show how the tidal system is perturbed. Finally we add oceans, continents and the influence of other forces, to complete a realistic interactive model of the tidal system. The user can add or remove the different elements of the simulation, the position of the moon (fixed or animated) and even change parameters like the distance and mass of the moon.

3. Conclusion

The simulations presented in this work are learning objects that, through virtual reality experiences, can actually enhance the understanding of basic Earth Science concepts for first year students. Our methodology is affordable and suitable for adoption by other developing countries' universities.

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