

INTRODUCTION TO THE 4-DIMENSIONAL DIGITAL UNIVERSE

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Abstract

We have developed 4-Dimensional Digital Universe (4D2U) theater. In the theater, the observational data and the theoretical models of astronomical objects are visualized stereoscopically. The astronomical objects range from the solar system to the “large-scale structure” of the universe. We have also produced the four-dimensional movies of various astronomical processes based on the results of computer simulations. In addition to these, we have distributed the products of this project through the Internet. As the next step of the project, we are now constructing 4D2U dome theater.

Keywords: visualization, astronomy, outreach, dome theater

1. Introduction

We have developed the 4-Dimensional Digital Universe (or abbreviating 4D2U, which is a homonym of “4-D to you”) theater. The purpose of our 4-Dimensional Digital Universe (4D2U) project is to visualize vast amount of astronomical data. We obtain the scientific data by super computational simulations and astronomical observations such as SUBARU telescope in Hawaii. These data can be visualized four-dimensional way by using computer graphics techniques and stereoscopic viewing method. Here, “four-dimensions” means three-dimensions in space and one-dimension in time [1].

There are two aims by developing and using the 4D2U visualization system. The first one is to provide the latest results of astronomical studies to laypersons on this field as correctly and intuitively as we can. The project team is based at the National Astronomical Observatory in Japan, which is one of the astronomical study centers in the astronomical society in the world. So we have an advantage to get the observational data from the world-class telescopes and the simulation data from the world-class supercomputers. The demonstration with 4-D system helps the layperson to catch up with the latest knowledge of astronomy.

The second one is to help astronomers in intuitively understanding their data or results by using an interactive 4-D View system. Today the interactive 4-D view system is getting important because the data dealt with researchers tend to have 3 or 4 dimensions and to be complex to understand unless without a 4-D viewer system. In this project, astronomers themselves take part to create rendered images and softwares. This is important in visualization in order to show the astronomical data in scientifically correct way.

We started the 4D2U project in the end of 2001. We have already introduced our project on the proceedings. In the present paper, we review the outline of the 4D2U project and report the present status of the project. In addition to them, we would like to report the ongoing project of the dome theater.

2. 4D2U - Theater Hardware

We developed the experimental 3-D projection system “4D2U theater” on late 2001. The theater’s screen consists of three 1.8m by 1.8m silver ones connected with the angle of 135 degree (Figure 1, 2). We adopted the circular polarization filter method to get the stereograph images. The slightly different images for left and right eyes according to the parallax are projected to each screen by DLP projectors through the polarization filters. By using polarization glasses we can see the stereoscopic images (Figure 3, 4, 5).

Each image is projected by one projector and one PC. As we have three screens and each screen has L and R images respectively, total 6 PCs synchronously project the images by communicating via Gbit Ethernet. The projections for each screen are folded by a mirror in order to obtain optical length. For the PC-to-PC communication, we developed the original TCP/IP-based communication software, with which we can play the movies at 15-30fps. The theater program is controllable with a game-pad connected to the main PC via USB. The experimental theater has a capacity of about 20.

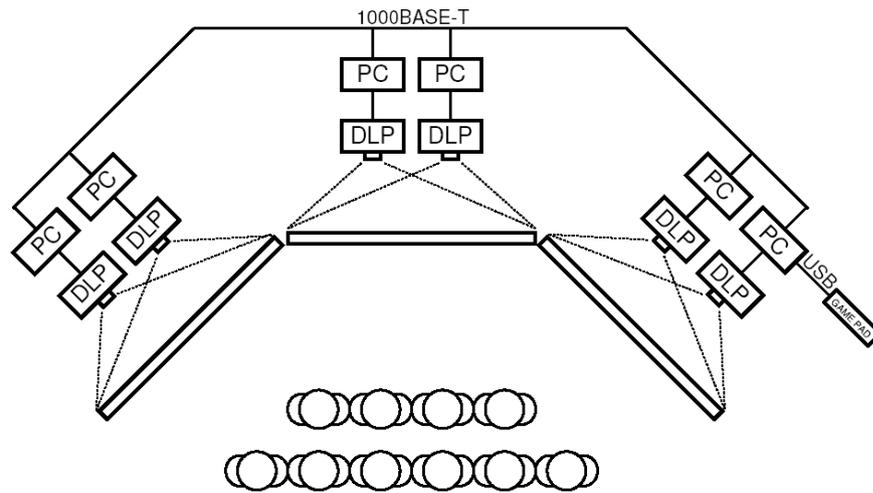


Figure 1. The schematic illustration of the 4D2U theater hardware



Figure 2. The outlook of the theater



Figure 3. L-R Projectors for each screen



Figure 4. Six PCs in the theater



Figure. 5. Polarization glasses

3. 4D2U - Theater Software

The theater software consists of two major parts: the static object data (observational and dynamic data) viewer “Mitaka” and the dynamical phenomena data movie player. By combining Mitaka viewer and short movie clips in our movie library based on simulations, we make some programs for a certain theme, subjected by “The Hierarchical Structure of the Universe”, “The Secret of the Milky-Way”, The length of typical program is 15 to 20 minutes.

The 4D2U system runs on WindowsXP PC. For GUI and movie play, we use DirectX library. For real-time 4-D rendering, we use OpenGL library. We may also use proprietary 3D CG software and post processing software in case of need for photo realistic expressions or color corrections.

3.1 4D2U Viewer: Mitaka

Mitaka is a real-time interactive viewer of astronomical objects. The astronomical objects span vast scales in space. From small scale to big scale, there are the Earth-Moon system, the Solar system, the stars in the Solar system neighborhood, the Galaxy, the local group of galaxies, the cluster of galaxies and the large-scale structure of the universe. The range covered by Mitaka spans from km scale to ten billion light-year scale. The structure of the universe is hierarchical. Mitaka can visualize such vast scales of the universe seamlessly. It can also play the simulation movies. Figure 6, 7, 8, 9,10and 11 show examples of the object data visualized by Mitaka.

3.2 Simulation Movie Library

The movie library is the collection of animations made from the results of computer simulations. The library covers simulations of many astronomical processes such as the formation of the Moon and the formation of the large-scale structure. For particle data such as stars we developed the special rendering engine Zindaiji. It can perform fast 3-D rendering for particle simulation.

We also use proprietary CG software when we want to have more photo realistic expressions. Figure 12 and 13 shows examples of the snap shots from simulation movies.

3.3 Music

Music is an important element when we show the program to the audience. We have a composer make original music in the theater for the show. Our typical program for the public has 15 or 20 minutes length. The music is composed as the same length and played with ProTools (hard disk recording system).



Figure 6. View by Mitaka: The Earth

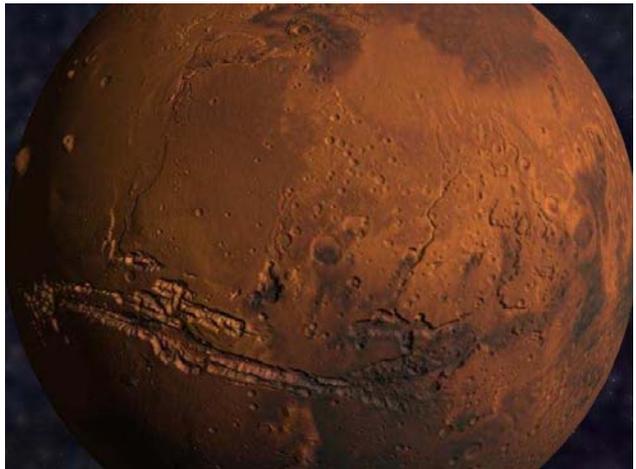


Figure 7. View by Mitaka: The Mars



Figure 8. View by Mitaka: The Jupiter and the satellite



Figure 9. View by Mitaka: The solar system



Figure 10. View by Mitaka: Our galaxy (theoretical model)

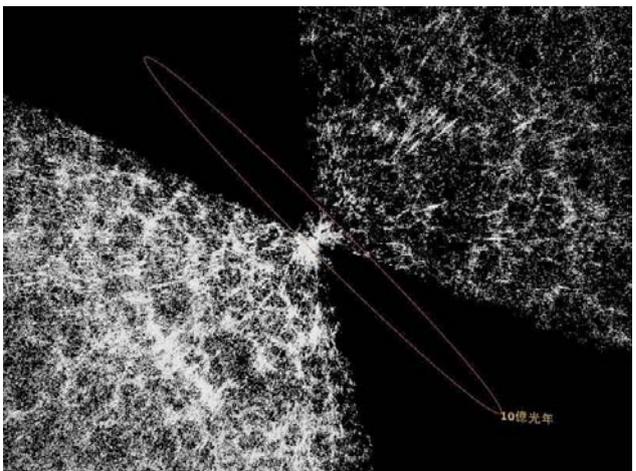


Figure 11. View by Mitaka: Large-scale structure of the universe



Figure 12. From a clip: "Formation of the Moon"



Figure 13. From a clip: "Formation of the Planet"

4. 4D2U as Outreach Activities

In this chapter, we report our social and outreach activities with 4D2U.

4.1 Mobile 4D2U system

We have also developed mobile 4D2U theater system. The mobile 4D2U theater system is the minimal version of the 4D2U. It consists of one portable silver screen and two cube PCs and two DLP projectors. The merit of mobile 4-D theater is easy to carry and can play anywhere. The difference of mobile 4-D system and original version of 4-D Theater is screen size. We have alternative movie library according to the screen size. Using this mobile system, we have been demonstrating 4D2U programs at more than several ten places such as schools, event halls, science museums in Japan. Although the screen size is smaller compared to the full system, it has been acquiring a reputation by audience at the lecture places.

4.2 4D2U Web site

Our web site (<http://4d2u.nao.ac.jp/>) provides the contents of our projects: pictures, movie clips, and documents. The software Mitaka and Zindaiji can be downloaded on the site. On this site, most of all of our resources such as movies and software can be downloaded. The site contains flush interactive program with which client can enjoy virtual tour on our universe through the Internet. It works as a minimal set of Mitaka. For this web design, we got an award of Japan Media Arts Festival in 2006. For viewing and downloading our contents, please check out the above project web page. You can find English download site of Mitaka [2], [3].

4.3 4D2U at Imiloa astronomy center of Hawaii

Imiloa Astronomy Center, formerly called "Maunakea Astronomy Education Center", opened on Feb. 2006 in Hawaii Island. It provides a scientific exhibition for visitors seeking to explore the connections between Hawaiian cultural traditions and the science of astronomy. We settled a copy system of the 4D2U theater in this center. People can enjoy our selected short program there. We have installed English, Japanese, and Hawaiian programs at the Imiloa center [4].

5. 4D2U Dome Theater

We have come into the second stage of the project since July 2004. We have been developing the dome screen theater system for 4D2U theater. In this new project we challenge to build the world first 4-D projection system on a dome screen. The exterior of the dome building is completed on March 2006 (Figure 14).

The building contains semi-sphere dome with 10m diameter. We have been developing the projection system with 16 projectors and 16 PCs. The color band filter method is adopted in order to get stereoscopic views. There are some difficult developing factors: the blending technique with multi projections and compensation for image distortion concerning with curved screen. We have been making effort to solve these issues. The alpha version contents of the dome theater will appear on 2006 summer.



Figure 14. The outlook of the new dome theater building

6. Summary and Discussion

We have developed the 4D2U theater system. The 4D2U data consists of the observational data, the theoretical models, and the simulation movies on astronomy. The basic methods for 4-D visualization of these data have been established. We have run the experimental monthly show to the public and met a good public response since 2002. In the show, we present our program not as a full automatic pre-rendered movie but as a live show controlled manually by ourselves. This is one of the important points to attract the audience.

7. Acknowledgements

4D2U project was supported by Research and Development for Applying Advanced Computational Science and Technology of Japan Science and Technology Corporation (ACT-JST). The web site design was made by Jun Kosaka. Our music is composed by Asako Miyaki. Dome theater project is supported by Special Coordination Funds for Promoting Science and Technology in MEXT (Ministry of Education, Culture, Sports, Science and Technology of Japan), Konica Minolta Co., and Goto planetarium Co..

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