Immersive Scientific Visualization

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Contents

Preface

Akito Arima and Shoken Miyama

Chapter 1: Perspective

Past, Present, and Future of Dome Movie
Koichi Ohmura 3

Seeing Science
Alyssa A. Goodman 9

Chapter 2: Scientific Visualizations

What is our "Science Culture Promotion Unit Through Astronomical Images"?
Shoichi Itoh, Hidehiko Agata, Tomoya Nagai, Hirotaka Nakayama,
Seiichiro Naito, Akira Hirai 15

The Making of Awesome Light I
Steven Savage 19

Supernovae
Akira Miura, Hiroaki Kokubu, Ginko Mochizuki, Takaaki Takeda,
Hirotaka Nakayama 25

Visualize the Reconstruction of Early Embryonic Zebrafish
Hitoshi Miura 29

HAYABUSA Back To The Earth
Hiromitsu Kohsaka, Ohmi Iiyama, Isshi Tabe, Makoto Yoshikawa 33

The Sun
Yuma Watanabe, Masaru Hirohashi, Masanori Iuchi, Mai Yonezu 37

"What do the Incan Constellations tell us?" The Views of Anthropology
and Astronomy in a Planetarium Session
Hanae Inami, Hatsuki Matsuoka, Kazutaka Koike, Susumu Oka,
Isshi Tabe, Kaoru Kimura, Seiichi Sakamoto 39

My First Experience of CG Movie Creation “Telescope - The Door to The Universe”
Masaru Hirohashi 43

Production of a Dome Movie “The Celestial Railroad" and Our Future Approach
Yutaka Kagaya 45

Three-Dimensional Animation by Electro Holography
Hirotaka Nakayama, Yasuyuki Ichihashi, Nobuyuki Masuda,
Tomoyoshi Ito 49

Chapter 3: Dome Theaters

Space Show Production at the American Museum of Natural History
Carter Emmart 55

About the 4D2U Theater of the National Astronomical Observatory of Japan
Takaaki Takeda, Eiichro Kokubo, Mitsuru Hayashi, Yumi Iwashita,
Hidehiko Agata, Junichro Makino, Syoken Miyama, Tsunehiko Kato,
Toshiyuki Takahei, Hikaru Okuno, Sorahiko Nukatani, Hitoshi Miura 59

Synra Dome, the First Public Stereoscopic Dome Theater in Japan
Toshiyuki Takahei 63

3D Stereoscopic Visualization at Imiloa Astronomy Center, New Datasets from the Maunakea Observatories
Shawn Laatsch 67

Immersive Scientific Visualization in Education, Storytelling and Art
Ed Lantz 73

Scientific Visualization Adoption in Domes and Digital Planetariums
Staffan Klashed 77

Immersive Dome Theater in Japan
Isshi Tabe 81

Chapter 4: Hardware and Software Development

Infitec Stereo System for Synra Dome at Science Museum Tokyo
Kiyonobu Fukusato 87

The New Style of Digital Planetarium from Field Use to Dome Projection.
Haruki Kamiyama 91

4K Transmission Experiments at Keio DMC
Kunitake Kaneko, Naohisa Ohta 93

Introduction to Immersive Projection Display : DLA-SH4K Projector
Hideo Kurogane, Ichiro Negishi, Tadashi Yano 97

Development of a 2.4K Full Dome Projection System Using a Fisheye Lens, SUPER MEDIAGLOBE II
Junji Nishigaki, Kazuhiro Takeuchi, Nobuhiro Ishimaki,
Mitsuaki Shimo, Akira Fukushima, Hiroaki Ueda 101

Auto Geometry for Synchronization between MEGASTAR Planetarium Optical Projector and Digital Planetarium
Takayuki Ohira 105

Introduction of Activity for Consortium of 3D Image Business Promotion and a Member's Case Study of Development
Kazuya Sawada, Toyohiko Hatada 107

SKY-SKAN Update - Projects, Products and the Future
Steven T. Savage 113

Quadratura, the Future of Real-Time Dome System
Toshiyuki Takahei 117

Author Index 121

PREFACE

The fields that scientific researchers are focusing on in 21st century are expanding rapidly and vastly year by year. And though their developments are deeply concerned with societies and lives of the people, it is getting harder for ordinary citizens who should support them to understand the cutting edge of scientific studies.

Scientific visualizations are supereminent media for such people to understand frontiers of science and technology. And they are also important for researchers themselves to increase the knowledge and understanding about their subjects, too. Particularly, visualizing technologies for looking into microscopic worlds and for reproducing evolution of the universe by the latest computer simulation have brought us astonishing worlds that were impossible even to imagine in the past.

Three dimensional movies on dome screens that surround us give the feeling as if we are immersed in space.

We believe this is a good opportunity to introduce such scientific contents and technologies to lots of people, and we hope it will give a chance of exchanging information to producers and technicians. We are planning to host "International Festival of Scientific Visualization" to provide the place to present new visualization contents for movie creators.

In this Preparatory Event 2009 we seek to find what the future International Festival of Scientific Visualization will bring to participants, both common people and professionals.

Akito Arima
Chairman
Japan Science Foundation

Shoken Miyama
Director General
National Astronomical Observatory of Japan

Chapter 1

Perspective

Past, Present, and Future of Dome Movie

Koichi Ohmura [1]

I am Koichi Ohmura at Takarazuka University of art & design. Before start to my talk, I'd like to apologize for my speech skill. My last speech in English was almost 30 years ago, so that my English may be very too rusty. I am afraid that you could not understand what I say. Anyway, I will do my best.

First, I will talk a brief history of dome movie. This is rather specialized topic than the history of computer graphics in general: I have worked for almost thirty years in the field of computer graphics.

１． LINKS-1

In 1982, I was in the department of electronics, Faculty of Engineering of Osaka University. At the time, I directed a research team of computer graphics in the Osaka University. In my computer graphics research group, 20-30 young artists and engineers joined. The first work of them was the development multi-processor system, specially dedicated for computer graphics. We call the system as “LINKS." This name has two meanings. One is the link between artists and engineers, and the other is the links of the systems.

Let's start a movie of 25 years ago, and I will make comments on them.

<START MOVIE>

This was a room of my laboratory of the department of electronics at Osaka University. This was the LINKS-1 System. All the system was all built by us and almost 800 micro processors work in parallel. The peak speed may be faster than the supercomputers at that time.

Fig.1. Laboratory of Osaka University

After this, we made an industrial system based on that. We established "TOYO LINKS Corporation" in Tokyo. TOYO LINKS is a computer graphics studio. This is TOYO LINKS. The company was a precursor of venture companies in now a day. Almost all staffs came from of our university.

Fig.2. LINKS-1

Fig.3. FUJITSU Pavilion in Tsukuba

[*1] Takarazuka University of Art and Design, Japan

Exposition

２． Tsukuba Exposition

In 1985, TSUKUBA exposition was open. TSUKUBA exposition was called as IMAGE EXPO., since almost all kinds of category of image presentations systems appeared, such as dome movies, lusty movies, and stereoscopic movies by both polarized or naked eyes. You saw the latest ones at that time. This was our project at FUJITSU pavilion. It was a dome movie in the stereoscopy: the images ere projected in red and blue and audiences watched them through blue and red glasses to see black and white images in stereo. The movie was divided into two parts. First half was an artistic visualization of the world of atoms and molecules. The last half was the artistic visualization of the world of sun and stars. These micro and macro worlds intermediated each other, i.e., from the macro world to micro world and from micro world to macro world. We used a dome with a diameter of 25m.

<STRAT MOVIE>

Fig.5. First Scene of “the Universe” in FUJITSU Pavilion

The title was “The Universe" and subtitle was “We are bone of stars."

The micro world was produced by Fujitsu’s supercomputer, directed by Dr. Nelson Max, who was a famous computer graphics artist and a mathematician, too. This is a micro world. This is a macro world. The macro world images are not so precise in the point of view of science but made according as the sense of artists.

This movie is a video version of the dome movie. The media of the original was a film. Therefore, it was transformed to the digital media by a computer. This is the sun, and the inside of the sun. There are helium nuclei. The time scale is extended by a large factor.

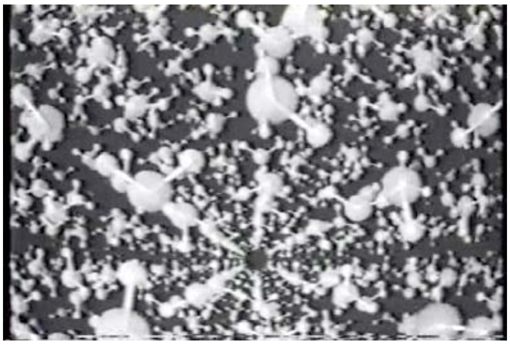

Fig.6. Water Molecules

Fig.7. Folding of DNA molecule

Here, you can see the water molecules to form ice from liquid water. This scene is rather difficult to make, since molecules are first in a disordered state (the state of liquid water) and changes to an ordered state (the state of ice). We overcome this difficulty by the following trick: we calculate the motion of the water molecules from ice (ordered state) to the liquid (disordered state) and played it backward. The computer graphics can do it easily, since simulations give us all the necessary information to do it.

In the sea of dark, Life was borne. This is DNA. DNA is very long, and must be folded, because chains of DNA have to be stored in a cell. We used a Fujitsu's supercomputer for almost one year.

3. Image Factory

Afterwards, I have moved to Takarazuka University of Art and Design and started school of artistic visualization in 1996. At the time, my university had no PCs and students had no knowledge on computers. That was the reason why I had to make a class to teach what a computer was and how to use it. In just this year, 1996, the personal computer era has started. So I decided to use a PC to make movies.
<start
movie>

Fig.8. Classroom of Takarazuka University of Arts and Design

This was my lecture room. This is me. There was a hand-made PC in front of me, and I made my lecture on how to use this PC. In the year 2000, just before their graduation, five students among them established their own company. Image Factory started 1986 as my private studio and young artists in the Image Factory they produced their own computer graphics. In this year 2000, I decided this name of Image Factory gave to their company.

Fig.9. A room of Image Factory

This is the TATAMI (straw mat) studio of Image Factory and there are several personal computers lied on the floor. I was only a maintenance engineer of them. This studio joined a dome movie project, which produced a full color movie for a dome for MINOLTA Planetarium Inc. This was the making process of a dome movie of 12 minuets. Since this was the very first of the dome movie. The staff was very few. This was a studio which had a dome with 16 meters of MINOLTA planetarium. This video was taken by a handy cam. The size was may be 1000 pixels. The movie was a Fantasy story. We used hand-made PCs, too, this dome movie was first presented in IPS, International Planetarium Conference at Montreal, Canada. The producer of the movie was the President of MINOLTA Planetarium Inc., Mr. Imai. He reported us that just after the play of the movie; every audience gave a cheer to our movie. Because a fantasy style movie was relatively rare in dome. Almost all the movies for IPS dome-movie were scientific. The story was on star constellation. This was the Milky Way and a white swan flies over the Milky Way and flies away. It took only one and half months to produce it. As you can see the staff roll, just seven staffs made this with hand-made PCs. Such a dome movie can be produced by such small resources in terms of both man-power and production time by means of the 2.5D technology of computer graphics. The 2.5D means the 2.5 dimension and 2.5 means that lie in between 2D and 3D. I will show you how to create a 2.5D movie.

Fig.10. Scene of Dome Movie

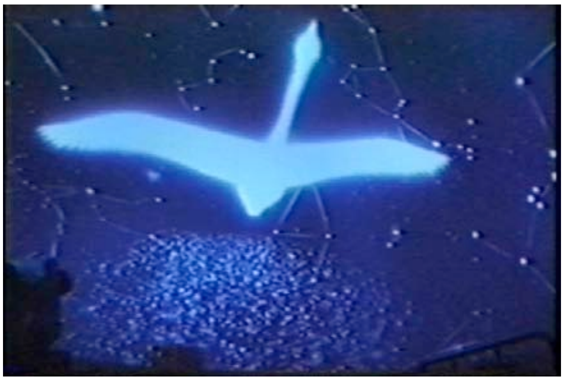

Fig.11. Fantastic Scene of the dome movie

The structure of this is very simple. Since it is a real-time computer graphics, we can change the angle. Look at this. It is not a 3-D graphics. There are transparent plates and square polygons. It is made by only fixed photographs or the plates painted by texture mapping. This is our technicality and the dome movie is produced by this technology. However, most important thing is not a technology but the philosophy underneath.

I will show you some sample. You will see these photographs: Clipping each object to making a picture. In the 3-d space, transparent traits are arranged. Each object is processed for the lighting, shadowing, and colors. You can see a cherry blossom. It is very fantastic, because this cherry blossom was taken in day time but the garden was taken at night. Because of the day-time cherry blossom in the night garden, this picture produces quite a curious impression. This movie shows the main concept of 2.5D. This idea is based on structuralism in the 19th century.

4. Concept of the 2.5D

I will show you the concept structuralism is on this image, with some samples. For example, there are four black lines; we see a white disc among them. This is a simple illusion which is famous in psychology. This white disc dose not exist in the actual graphics, but for me, it dose really exist among four black segments of lines. If this nice relation changes, the white disc disappears. We can see this impression become of the relationship of four straight lines relationship arrangement four black lines. This structural of the system produces the impression of white disc in our mind. So we can see this white disc dose not it is physical drawings. These four relations of a black straight line create a white disk. In this case, the relationship is most important things, nor the physical portions. In the 2.5D concept, this clipping photographs and arranges it into space. The relationship distance change makes us seen white shape in the daylight cherry in the night garden. It is a new wave of graphics one of the examples of the structuralism. This structuralism is most important way of thinking in 20th century.

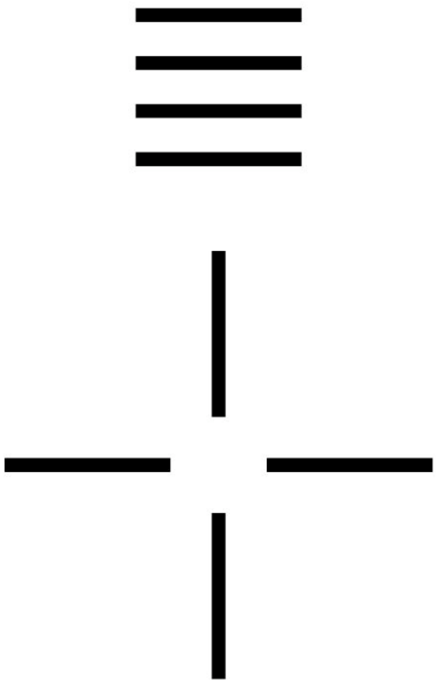

Fig.12. White disc can bee seen on the center of four lines.

This is a main concept 2.5D movie but is originated to physical science. In the nature, an energy state of a heavy element is not important by itself; In fact, nature of an element is determined by the relationship to all the other elements involved in the situation.

The most important is relationships between the elements and their aggregation of them. In physical science nowadays, most important is the mutual interaction between particles, atoms, and molecules but not their selves. So visualization and studio-art are conceptually close to physical sciences.

Fig.13. Pictures are clipped

Fig.14. A picture is synthesized from the clipped pictures.

Finally, I may say that the concepts of scientific visualization and artistic visualization are quite similar. The collaboration of two types of visualizations must be fruitful and productive for each other. In future artists, scientists, and engineers can collaborate to make a super dome movie. That is art of scientific visualization.

Thank you.

(The manuscript was written by M. Eto and T. Ebisuzaki based on the talk at the opening ceremony on March 13, 2009)

Seeing Science

Alyssa A. GOODMAN[1,2]

The ability to represent scientific data and concepts visually is becoming increasingly important due to the unprecedented exponential growth of computational power during the present digital age. The data sets and simulations scientists in all fields can now create are literally thousands of times as large as those created just 20 years ago. Historically successful methods for data visualization can, and should, be applied to today's huge data sets, but new approaches, also enabled by technology, are needed as well. Increasingly, "modular craftsmanship" will be applied, as relevant functionality from the graphically and technically best tools for a job are combined as-needed, without low-level programming.

1. Introduction

The essential function of data visualization is to offer humans a way to see patterns in quantitative information that would otherwise be harder to find. Many people today believe that computers can always find these patterns as easily, or more easily, than people can. The people who do *not* believe computers have this power fall into two groups: researchers who strive to create tools as good as humans, and small children (who have not yet been indoctrinated to believe that computers are superior computers to humans in all ways!). The most productive research in data visualization today is focused on developing *technology to augment the human ability* to find patterns.

2. History

Before the introduction of the computer into science, data visualization took two forms: 1) hand-drawn sketches made by researchers themselves; and 2) professionally-drafted illustrations. Some "conventions" for making these drawings did develop (e.g. Cartesian coordinates), but the makers of early scientific drawings were free to draw upon or create whatever tools and rubrics were most appropriate to their tasks, conventional or not.

As computers entered the picture, several important changes took place. First, on the upside, the amount of data scientists could generate and analyze began to rise very rapidly, and the alternatives available for how to display it (e.g. animation, 3D graphics) began to expand. On the downside, the tools that were developed to put data visualization into the hands of the scientists themselves typically offered nowhere near the level of flexibility and craftsmanship that the combination of hand-drawing and professional draftspeople could. As a simple example, think about how easy it is for a person to write a name along a curving river or street in a map (Figure 1), but how much harder it is to get a computer to do that just as well.

Today, the very best tools available for data analysis and visualization are being developed with

Fig.1. An historical map of Edo (1844-48). Notice the craftsperson's attention to orientation in the labeling, and the beautiful details of illustration. [1]

attention to the kinds of graphical details and functionality that the work of draftspeople used to add to science. Below, I argue that what is needed now is for high-craft tools to be made modular and interoperable enough so that scientists can combine the functionality offered by various systems into ones where "modular craftsmanship" is possible.

3. Data • Dimensions • Display

Formally, we can frame visualization challenges by thinking about interactions amongst *data*, *dimensions*, and *display*. Some *data* to be visualized arise from continuous functions (e.g. fitting), others come from discrete measurements (e.g. observational/experimental data). Some *data* sets are inherently large and others small. Most data sets have either an inherent *dimensionality*, or dimensionality imposed when a choice is made about what quantity/quantities are to be explored/displayed as functions of others. For example, brain imaging data is often three-dimensional, but is often displayed as a series of two-dimensional slices. Oftentimes, it is the nature of a *display* mode (e.g. monochrome vs. color, paper vs. electronic, static vs. dynamic, etc.) that sets boundaries on what *data* are *displayed* with what *dimensionality*.

The word "dimensionality" should not be taken too literally. In some cases, such as medical, geospatial or astronomical data data, there are natural

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[1] Professor of Astronomy & Founding Director of the Initiative in Innovative Computing, Harvard University
[2] Scholar-in-Residence, WGBH Boston

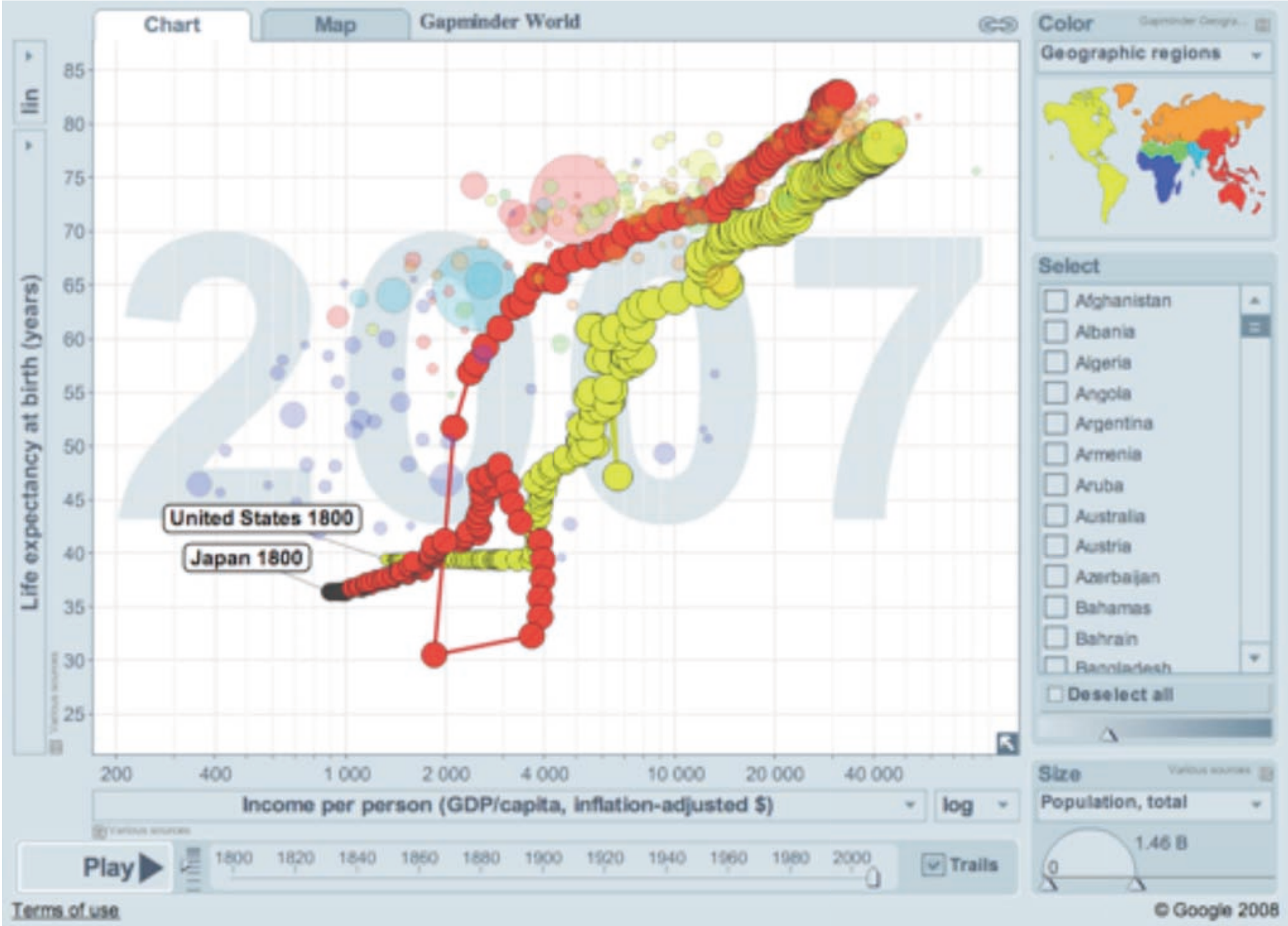

Fig. 2: A snapshot of the "Gapminder" web tool (from http://www.gapminder.org) as applied to data showing life expectancy vs. income, highlighting the U.S. and Japan. In an online version of this document, click here to try out the interactive features of this graph. The Gapminder tool was originally developed by Dr. Hans Rosling, in conjunction with the development of the Trendalyzer Software Package. Trendalyzer was acquired by Google, Inc. in March 2007.

coordinates, with a natural number of dimensions (typically 3 plus time) in which one can display sensed quantities. Often, that kind of "natural" display is particularly useful. But, even in fields offering what seem "natural" combinations of dimensions, there are often abstract combinations of "dimensions" (e.g. a 3D plot of global temperature vs. time and wealth) that are equally or more instructive. And, in fields of study without natural spatial dimensions (e.g. wealth management) abstract combination of variables, for analysis in multi-dimensional space, is the norm.

So, then, the general challenge in "Seeing Science" is to create and use tools appropriate to the kind of *data* available, with regard to the data's either natural or potential *dimensionality*, whilst taking into account the constraints-—or opportunities —offered by particular form factors of *display*.

4. New Options

Some of the options open to us today for displaying our data are essentially the same as, or very closely based on, those open to the previous generation of scientists. For example, an *x-y* graph using different symbols to indicate one or more measured "*y*" quantities is still often an excellent option for exploring data or communicating its import.

Fig. 2 shows a static screenshot of a(n interactive) graph created using the gapminder.org web site [2]. The central panel of the Figure essentially is just an *x-y* graph of the relationship between life expectancy and time for the U.S. and Japan from 1800 to 2007. This graph on its own is quite informative, and for the purposes of a two-*dimensional*, static, printed, document like this one, it is a suitable *display* of these *data*.

Yet, as the many grey-backgrounded panels around the central one in Fig. 2 suggest, much more interactive investigations are possible when *display* features not typically available to previous generations are used. As users of gapminder (or, more generally, "Trendalyzer" or "Motion Chart" [5], know, graphs are generated after users interactively select which data sets to explore (notice the panel at the right in Fig. 2, listing the selectable countries.) Then, users can hit the "Play" button, to see relationships evolve over the range of time selected in the panel at the bottom, and the *animated* time series generated can be recorded (and thus summarized) as the *x-y* graph you see in Fig. 2. The size of the symbols used in fact represents a third "*dimension*" of information in these *displays*, as it is set to be proportional to a country's population.

The "Map" tab at the top of Fig. 2 allows users to display the same global health *data* sets that underly all of gapminder.org in a "natural" geospatial context. Yet, the geospatial view is not always the most relevant in studies of global health, and the greatness of gapminder comes from the flexibility it offers users to explore or demonstrate relationships within and amongst *data* sets, using more than two *dimensions* at once, by making use of the options offered by a dynamic, color, two-dimensional *display*.

Keep in mind that the word "*dimensions*" here really means "variables." In that sense, Fig. 3, at right, shows what looks like a "three dimensional" view of gas in interstellar space, but in fact, only two of the dimensions are purely spatial ("R.A." and "Dec". are coordinates measured on the sky). The third dimension is "*vz*", a velocity measure that can be used to separate objects that otherwise project on top of each other in plane-of-the-sky-only (2D) views. The paper from which Fig. 3 is drawn seeks to study relationships between the objects shown with darker shading, but even with the static 3D visualization shown here, those relationships are not sufficiently apparent. Instead, it was necessary to publish the paper *displaying* the figure in a way that allows the user to "turn" the figure around in arbitrary directions, so that expert readers of the paper can see for themselves how connected or disconnected features are from various vantage points. So, the *data* were *displayed* as an interactive "three-*dimensional*" figure (see caption) that presents as a pretty-good display on a static page, but as a much better, more informative, one on an interactive 2D computer monitor.

Both gapminder (Fig. 2) and 3D publishing (Fig. 3) offer new insights into more *dimensions* of *data*, when more aspects of *display* technology are used.

Yet, the options offered by technology can be overwhelming, which today leads both to their under- and over-use. Many researchers are presently unaware of re-usable tools like the software that underlies gapminder.org, or the 3D capabilities of Adobe Acrobat and other programs[3], which leads to under-use. Conversely, when researchers whose main talents lie in their domain specialty, and not in graphics or visualization, encounter new tools, they sometimes over-use the tools to the detriment of communicating their science. For examples of that kind of over-use, think about all those mid-to-late 1990's web pages with gratuitous spinning things, flashing lines, and crazy colors, when html first came to "everyone." Or, worse, think about bar graphs made in Excel using "three-dimensional" bars where the third dimension has no meaning at all.

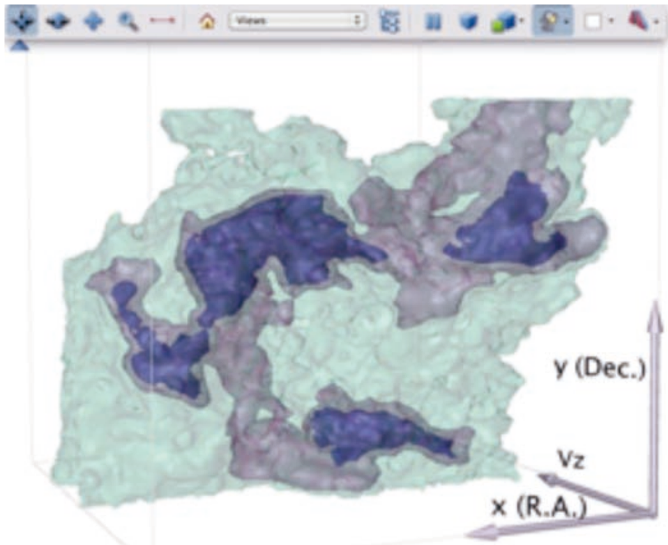

Fig. 3: A "three-dimensional" interactive figure, showing the structure of gas in a star-forming region, based on the figure published as the first "3D PDF" in the scientific journal *Nature* [3, 5].

Thus, today's scientists find themselves presented with a dazzling array of new, high-tech, tools for displaying data, but not always with enough expert guidance to use those tools to maximum advantage. Further, scientists often discover that the great new tools do "almost" exactly what they need, but not quite. So, the choice becomes: use the "same old" software used in their specialty for years; or spend large amounts of time and money (which they usually do not have) re-inventing software someone else has *almost* created for them.

5. Modular Craftsmanship

It is well-known that the data visualization and analysis challenges faced by nearly all fields of quantitative research are largely shared [4]. They are not, however, fully identical. Programs intended for generalized data analysis and display, most notably Microsoft Excel, are fine at some level of analysis, but are usually not an end-to-end solution. They also do not, by default, produce "optimal" graphical

[3] This paper includes a special web-links bibliography [reference "5"], at its end, which provides information on relevant web sites and software, as of November 2009.

displays or handle the special needs (and/or formats) of particular disciplines.

In other aspects of scientists' lives, they are offered opportunities to use software in modular or configurable ways. For example[4], when the same scientist who struggles to find or build the right visualization tool for her data wants to figure out which hotel to stay in for a meeting, a plethora of choices to retrieve (hotels.com), compare (kayak.com) display (Google Maps API) and archive (browser bookmarks) and organize (e.g. TripIt.com) a travel search is available. And, those services can be easily organized (iGoogle) and combined into customized, re-usable (kayak.com) searches and tools.

The same kind of modularity and interoperability should be possible when it comes to creating interactive, high-dimensional, graphical displays of data. We are beginning to see an overall move toward more agile software architectures, so it is not as hard as it once was to envision how the opportunities for "modular craftsmanship" in data visualization could become commonplace.

So many of the challenges inherent in visualizing high-dimensional data on standard displays are shared, that modules which each handle a different kind of data/dimensional combination can be envisioned. Google's creation of open Visualization APIs is clearly a step in this direction [5].

Today, astronomical imagery is often best displayed using modular tools and APIs spun off from commercially-viable software designed for viewing geospatial data and/or for gaming. Google Sky came from Google Earth/Maps and the associated Google mapping APIs [5]. Microsoft's WorldWide Telescope [5] is enabled by DirectX, a collection of APIs developed primarily for running games.

6. The Future

In the future, it will be necessary to train scientists and learners to "see" science using an ever-changing, but easy-to-combine set of tools. It is up to today's scientists now to work as closely with today's craftspeople (software developers) as they did with yesterday's (draftspeople) to create the tools we need to accomplish the ease and flexibility in data visualization "modular craftsmanship" should allow.

And, thanks to the increasing volume and use of quantitative information in all aspects of our lives, much of the visualization software developed for commercial purposes can be re-used within the scientific community. In cases where challenges are directly shared, as is the case with, for example geospatial and astronomical data, public-private (scientist-industry) partnerships can easily be imagined, and should be pursued.

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2. Rosling, H., Rosling Rönnlund A., Rosling, O. 2005, in *Statistics, Knowledge and Policy: Key Indicators to Inform Decision Making*, ISBN -92-64-00900-0, p. 522.
3. Goodman, A.A. et al. 2009, *Nature*. 457: p. 63-66.
4. Wilkinson, L. 2005, *The Grammar of Graphics*, (2nd edition), Springer
5. **Consolidated web link references**:

Visualization Tools for Data with "Spatial" Coordinates

- Google Maps/Earth/Sky: available through http://www.google.com
- WorldWide Telescope: http://worldwidetelescope.org

General Tools for Visualizing, and Discussing, ASCII data online

- ManyEyes: http://manyeyes.alphaworks.ibm.com/manyeyes/
- Swivel: http://www.swivel.com/

APIs, Gadgets & Plug-ins

- *Google Gadgets* (http://docs.google.com/support/bin/answer.py?hl=en&answer=91610)
- *Google's "Code Playground":* http://code.google.com/apis/ajax/playground/ Motion Chart and other charts are under "Visualization APIs"

Modules for Interactive Data-Driven Graphics

- *Processing*: http://processing.org/ an open-source language and environment for people who want to program images, animation, and interactions

Sky-Viewing Tools

- WorldWide Telescope (http://worldwidetelescope.org)
- Google Sky (http://earth.google.com/sky)

3D Publishing

- Sample file, re:Figure 3, (http://iic.harvard.edu/sites/all/files/interactive.pdf), produced using 3D Slicer (http://am.iic.harvard.edu/index.cgi/UsingSlicer), Right Hemisphere's Deep View, and Adobe Acrobat Pro Extended edition

[4] The methods and travel-related web sites mentioned in parentheses in this paragraph are current as of November 2009. They are chosen as representative, and citing them is not intended as an endorsement by the author.

Chapter 2

Scientific Visualizations

What is our "Science Culture Promotion Unit Through Astronomical Images"?

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National Astronomical Observatory of Japan (NAOJ) has started a new project, the Science Culture Promotion Unit in collaboration with Mitaka City Government, supported by providing grants-in-aid for Science and Technology Promotion of the Ministry of Education, Culture, Sports, Science and Technology since 2007. The aim of the project is to help bring up (1) talents who create astronomical visualized images with scientific accuracy based on theoretical calculation, and (2) talents who popularize science for people in general, through astronomical images that National Astronomical Observatory keeps in store, such as the contents of 4D2U, the four-dimensional digital universe project, and the images taken by Subaru Telescope and others. This project has this for its objective that the contents and techniques using them will have the added value in next generations. NAOJ tries to make a contribution towards Mitaka City becoming the internationally fit place for creating the three dimensional contents in the future[1].

1. The course for bringing up leading contents makers

NAOJ seeks to encourage two types of talents. "Scientific Image Creators" produce valuable image contents using the fruits of astronomical and scientific researches with stereo and dome theatrical techniques.

"Science Producers" set out with the new purpose of searching the public needs, sharing scientific information with general public, and then utilizing scientific resources for people in general. Science Culture Promotion Unit (SCPU) will encourage them to improve their ability and skills throughout the course and will continue to support their activities when they have finished the course.

2. Scientific Images for Everybody

The Universe—How our present world has become what it is and how to keep our world as it is.

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NAOJ keeps a large stock of such true scientific resources from the pictures which SUBARU, the gigantic telescope, has taken in deep space, to dynamic simulations produced by GRAPE, the Japanese supercomputer with the fastest record holder in the world.

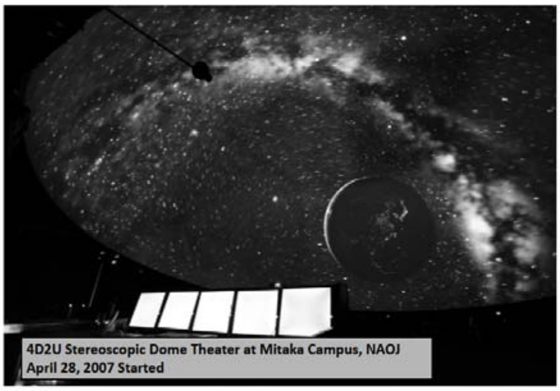

Fig.1. Snap shot of 4D2U.

We have installed 4D2U stereoscopic dome theater at Mitaka campus, NAOJ. It was opened for public since April 28, 2007.

The contents of 4D2U Theater, such as mathematical simulations by supercomputer, observational data from NAOJ site's telescopes, were developed by researchers of NAOJ.

We seek to build 4D Digital Universe Theater

Network connecting with schools, educational facilities, museums, planetariums, and each homes.

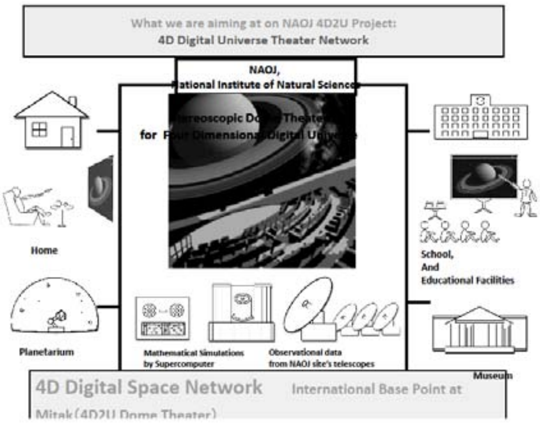

Fig.2. 4D Digital Space Network

The users can download the software "Mitaka" and simulation movies created by the calculations by supercomputer.

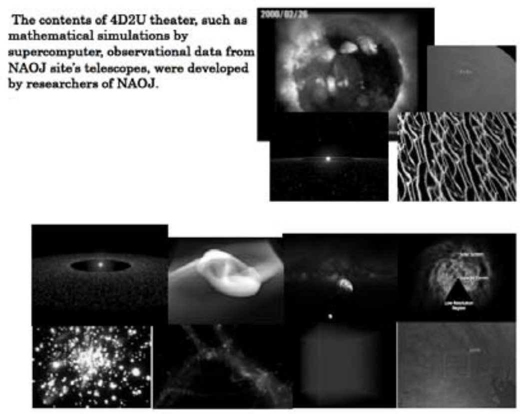

Fig.3. Samples of 4D2U contents. Photos are including stereoscopic X-ray Images by Yokoh and simulations of planetary formation, saturn ring wake, formation of binary stars, distribution of neutral hydrogen gas and hydrogen molecules in our Galaxy, cD galaxies, formation of spiral galaxy, formation of large scale structure in the universe and etc..

"Mitaka" is software for visualizing theoretical, computational, and observational astronomical data, developed by the Four Dimensional Digital Universe (4D2U) project of the National Astronomical Observatory of Japan (NAOJ). Users can seamlessly navigate across the universe from Earth to the edges of the known universe. Mitaka is optimized for 3D visualizations on multiple screens at the 4D2U Theater in NAOJ's Mitaka headquarters. However, it can also be used on a single Windows PC.

4D2U, the four-dimensional digital universe project, by which people can experience the extent of vast space and time expressed by the stereoscopic view of cosmos in the cutting edge, shows the new possibility of astronomical images and has received high valuation.

To popularize the catchphrase, <4D to you: four-dimensional universe to you>, the talents brought up by the SCPU will develop a network for making people scientifically-minded and future-oriented.

3. The city where science promotes the culture

"The accumulation of knowledge" will prove fruitful for the town. To use science as the resource of society, SCPU was organized in collaboration or partnership with private firms, research facilities, industries and the public.

Mitaka City, where NAOJ is located, is the place where the citizens feel find astronomy familiar. It is also well known as the integrated place where animation studios as well as movie industries gather. SCPU will bring new values and respectability to the city of Mitaka by promoting training of (a)talents who create visualized images produced by 4D2U: Science Image Creator Training Course, and (b)talents who popularize science among the general public: Science Producer Training Course.

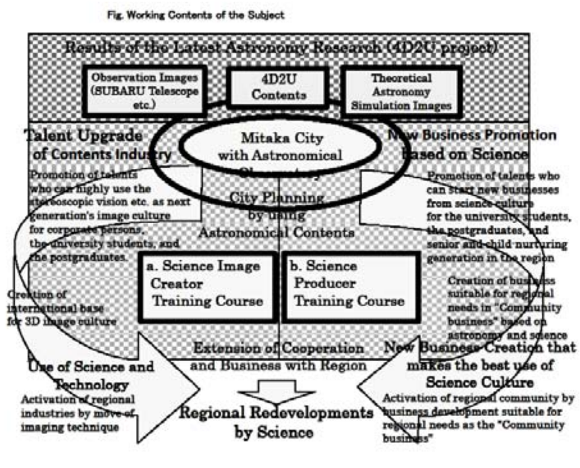

Fig.4. Schematic diagram for activities of SCPU.

4. Collaboration between NAOJ and Mitaka City

We will further explain our idea and flow of this project in figure 5.

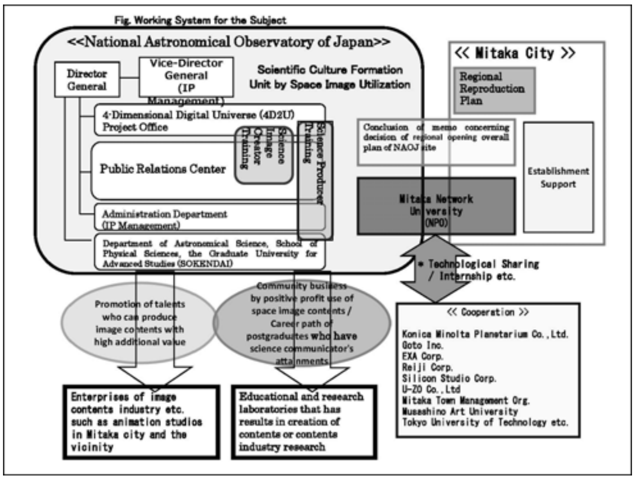

Fig.5. Schematic diagram of collaboration between NAOJ and Mitaka and the flow of our activities.

This is the detailed schematic diagram of collaboration between NAOJ and Mitaka City and the flow of our activities. Actually, NAOJ and Mitaka City have made a comprehensive contract of cooperation with each other.

Mitaka Network University that is supported by Mitaka City Government, universities, research facilities including NAOJ, private firms and industries in the vicinities of Mitaka City, hosts several programs concerned astronomy under the cooperation of Mitaka City Government and NAOJ. NAOJ is also occasionally supporting the operation of the Salon of Stars and Winds, and the House of Stars and Woods at NAOJ Mitaka Campus, which are administrated by Mitaka City.

The talents brought up by the SCPU will contribute to produce programs for such facilities.

5. Conclusion

Finally we would like to emphasize the meaning of our project.

Space is a Jewelbox of Wonders for humankind.

So, we will put to practical use our astronomical resources such as astronomical images through Scientific Image Creators and Science Producers, and let rise new science culture at Mitaka.

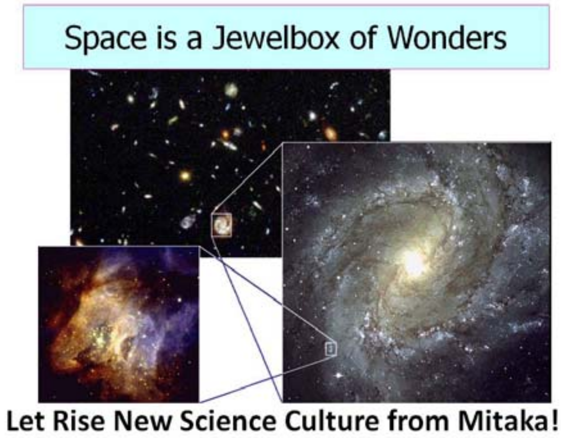

Fig.6. Space is a Jewelbox of Wonders

We are now acting various plans such as mentioned here for realizing or promoting science culture mainly in Mitaka area. The final targets of SCPU as our actual designs are as follows:

1, Fixation of intellectual property rule for National Astronomical Observatory of Japan.

2, Career path making for postgraduates who don't become astronomers (Starting New Businesses etc.)

3, Solving Problem of declining birthrate and graying of urbanized society (Synchronization with regional redevelopment plan of Mitaka city)

4, Holding International Science & Image Festival.

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THE MAKING OF AWESOME LIGHT 1

Steven T. SAVAGE*

Immersive movie making in fulldome – The making of Awesome Light 1 - 3D
Stereo Photography in Hawai‘i, from the Sea to the Summit of MaunaKea and its 11 Observatories.

1. Introduction

I will present a short synopsis about capturing the time-lapse photography in *Awesome Light 1*, the production that was shown last night. This was a very low budget production and it required a lot of clever photographic techniques in order to get some real imagery of live action up on the screen. The following are production shots:

Fig. 1 – Hilo, Hawai‘i

If you've been to Hawaii before, especially to Hilo, this is the sort of romantic night-sky scene that you would see at the beach. Most tourists have no idea that there is incredible cutting-edge astronomy being conducted on the top of Mauna Kea (the mountain seen here in the distance). Most visitors are out seeing volcanoes or drinking or hanging out at the beach. So this is an interesting time to explore some of the cool science that happens at the top of the mountain.

Fig. 2 – ‘Imiloa Astronomy Center, Hilo, Hawai‘i

Sky-Skan responded to an RFP from the ‘Imiloa Astronomy Center. They wanted to do a stereo production at a very low budget. We said "O.K., we can do that." The shoot resulted in 144,626 frames, shot in stereo, over 9 days. We were equipped with a pair of Nikon D-300's and a pair of Canon 5D's, used by two photography teams.

2. Day 1 - The Blue Screen

The first day started in the back lot where we put together a blue screen setup to capture the characters of the Hawaiian gods and their progeny. We used a high-definition stereo video camera rig.

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I want to thank Shawn Laatsch for a lot of these production shots. He was the production photographer as we were capturing the scenes.

Fig. 3 – Actors representing Hawaiian Gods in front of blue screen.

These are our two characters (fig. 3) that represent the original Hawai'in gods who had a son and a daughter. Here, we're setting them up and giving them direction on what kind of action we wanted to see.

We'll see the blue screen scenes of the actual photography, and then show how these shots go into a compositing process where the blue screen is removed and we treat their skin textures to get the more classic Hawai'ian look.

Fig. 4 – Compositing in DigitalFusion

All of these pieces were put through a dramatic process to get the effect that we want where we layer the background and other elements. This particular shot was quite difficult and has about 140 edit nodes - you can see about 30% of them here in DigitalFusion (fig. 4). The finished shot is the following video. This sequence sets the tone for the kind of mystique of the Hawai'ian culture.

3. Day 2 - Canada-France-Hawaii Telescope

The next morning we made our way to the top of Mauna Kea to shoot the Canadian-French-Hawai'ian Telescope (CFHT). We set up the cameras with a grid to make sure stereo calibration hadn't changed from the transit to the top of the mountain and we proceeded to take our first mountain top sunset scene. (fig. 5).

Fig. 5 – CFHT at Sunset

4. Day 3 – Waterfall

The next morning we were back down on the coast to shoot the waterfall. This is the one we wanted to capture. We set up cameras, we're all smiling but it wasn't going to work. So Jack White found another waterfall but I said, "Too small." and so we found a medium-sized one that we could actually get close to (fig. 6). We set the shot up and it worked quite well. The canopy overhead gave us a nice 3D effect.

fig. 6 – Shooting the Waterfall

5. Day 4 – Inside Gemini

We were back on the mountain again and shooting the Gemini North Telescope. We climbed up to this gantry (fig. 7) which is a gorgeous viewpoint, so that the telescope would swing around in front of the camera and provide a great stereo experience.

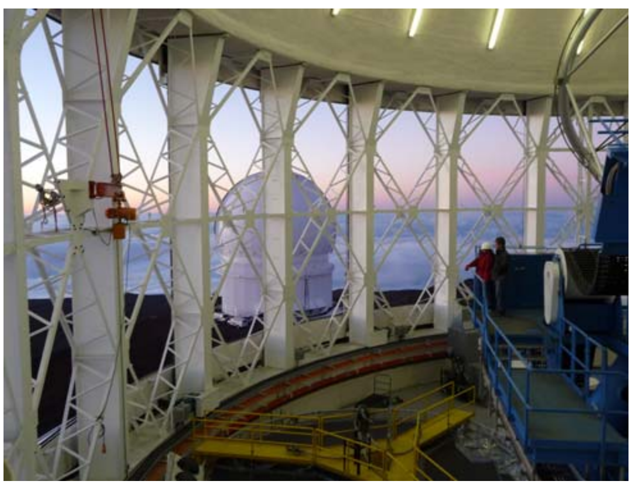

Fig. 7 – Interior Gemini North

When these gates opened, I thought, “It’s so beautiful!” I wasn’t paying attention to the photographing because the view was just stunning. But we finally got back to work and photographed this scene that was in the show.

As you may know, Mauna Kea is a volcano. We were working up at the top most days and there was just one small road to go up and down. We went back and forth every day, which was a very difficult situation.

So we took up rooms at the mid-mountain lodge at 9,000 feet. We slept there and went to the very top every day, which is about a 40 minute journey.

6. Day 5 – Inside CFHT

The next morning we were back at CFHT while they were doing maintenance. In this particular shot (fig. 8), we were looking up at the base of the telescope.

Fig. 8 – Shooting the base of the CFHT

You can see we set up the rig at the base of the telescope and put in some lights so we could see some detail in the black area where the mechanics were located and in the end we had a very nice shot. You might remember the red tag that was hanging down – its distance is just at the closest limits of where you can put the cameras for 3D stereo.

7. Day 6 - Subaru

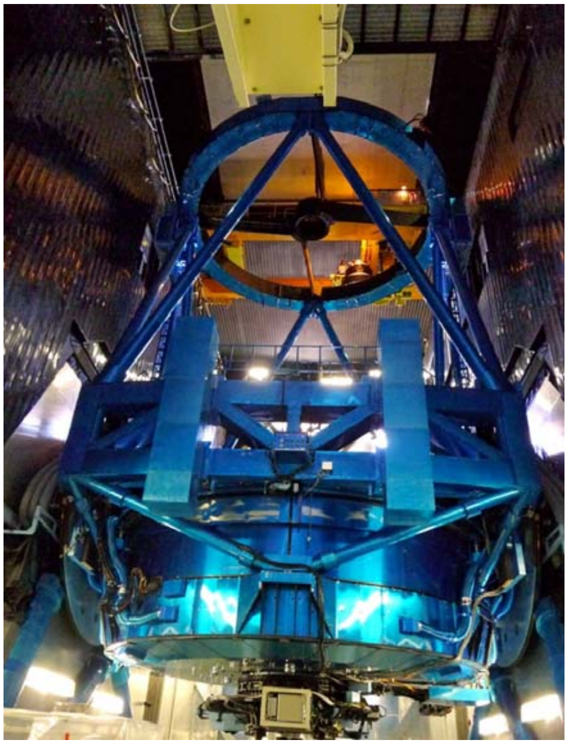

Fig. 9 – The Subaru Telescope

The next day we were at Subaru. You might just be able to see the man up there on the gantry (fig. 9). He is changing the instrument at the prime focus position and will drop it on a carousel.

These are the actual prime focus instruments and they have a carousel (fig. 10) where they house different instruments that focus on different science. The arm comes out and picks the instrument up.

I will show video here – this sequence was too long to make it in the show. You can see where they pick off the instrument from the prime focus position. It actually moves quite slowly and it took all the morning to make this move. It's like changing lenses on your camera. After lunch, they load the next instrument back on for that evening's science.

Fig. 10 – Changing the instrument

When the arm comes across, the team outside will be ready to receive the new prime focus instrument and will drop it onto the telescope.

The Subaru is one of the most unique instruments on the mountain – it's amazing.

8. Science from the Mountain

The astronomy sequences for the show were produced in DigitalSky using datasets derived from research at the three observatories (fig. 11). About 18,000 of these frames were produced in DigitalSky's Stereo Renderer. The whole production was completed within budget.

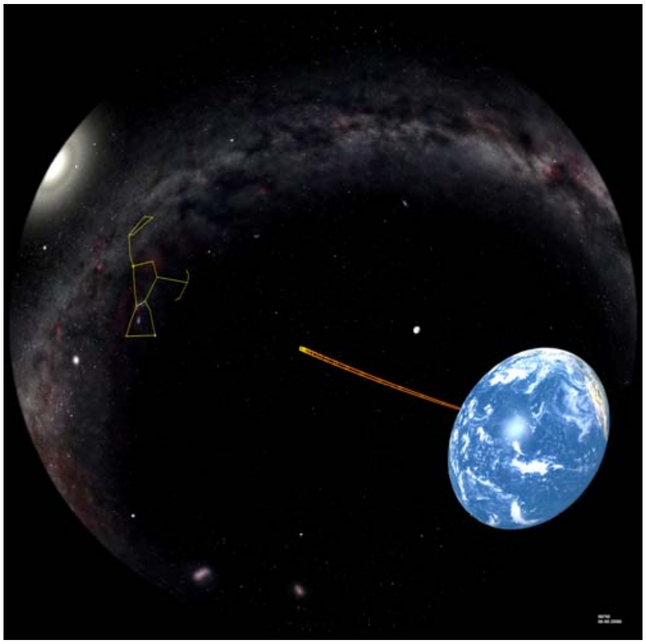

Fig. 11- Datasets imported from CFHT, Gemini, Subaru; finished compositions layered in Digital Fusion; 4K CG scenes rendered in DigitalSky Fulldome Stereo Renderer

9. Leaving the Mountain

As we were going down the mountain on the last night we saw a laser beaming into the night sky. It was the Laser Guide Star System being propagated from the Keck Telescope (fig. 12).

Fig. 12 – Keck Telescope and laser guide star.

10. Conclusion

Awesome Light 1 is attracting a lot of attention because it is the first full dome production to use photographed scenes in very low light, other than those rarely captured by the expensive large-format film method.

While the production of high-quality stereo timelapse photography for the dome is technically difficult, the results on the screen are very effective. Moreover, the digital capture costs are relatively low when compared to any other motion picture cinematography.

As digital capture devices become faster and frame resolutions continue to improve, the use of this format for landscapes and action shots is likely to replace that of large-format motion picture cameras.

Supernovae

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Abstract

We have compiled episodes related to supernovae. The movie consists of several parts. Part 1 describes historical episodes. In AD 1006, there appeared a very bright guest star (supernova) in the constellation of Lupus, as was described by many observers. The star was also seen in Heian-kyo, the capital of Japan in those days. Visualized in this part is a fly-through of Heian-kyo and a vision of the Four Symbols. Part 2 describes astronomical episodes. X-ray astronomy satellite "Suzaku", which was named after the bird guardian of the South (one of the Four Symbols), took a picture of the millennium of the supernova of AD 1006. This part also shows the structure of “Suzaku” and the X-ray telescopes that “Suzaku” mounted. Part 3 is a gallery of astronomical images: the ROSAT X-ray all sky map and pictures of supernova remnants in various wavelengths. Part 4 describes the beginning of a supernova explosion. This part shows a typical figure of the inner structure of a star just before the explosion, and then visualizes a computer simulation of supernova explosion. The last part shows ASTRO-H, the new exploration X-ray telescope, and another Image gallery superimposed on credit titles.

1. Introduction

This is a work of the Science Image Creator Course at the Science Culture Promotion Unit through Astronomy Images. We have studied astrology and astronomy about supernovae and made a stereoscopic movie for dome theaters on the theme of supernovae.

A supernova is a catastrophic explosion of a star at the end of life. Supernovae bring a variety of elements that is formed into almost everything in the world.

Our team consists of three students (Akira MIURA, Hiroaki KOKUBU, Ginko MOCHIZUKI) and supervisors (Takaaki TAKEDA and Hirotaka NAKAYAMA).

We began to make the movie in Oct. 2008 and completed the work in Mar. 2009. We used Autodesk Maya, Shade Professional, POV-ray for three-dimensional modeling and rendering, Adobe Creative Suite and ImageMagick for editing.

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2. Contents of the movie

The movie is a compilation of episodes related to supernovae.

(1) Historical episode (astrology): This part describes Heian-kyo and the supernova of AD 1006. In AD 1006, there appeared a very bright guest star (“Dai-kakusei” in Japanese) in the constellation of Lupus. The star was also seen in Heian-kyo, the capital of Japan at the time. In the 20th century, the star was found out to be a supernova.

(2) Astronomical episode: X-ray astronomy satellite “Suzaku” was named after the bird guardian of the South. This part shows the structure of “Suzaku” and X-ray telescopes on it combined with the millennium of the supernova.

(3) Image gallery: This part shows all sky views in X-ray and several images of supernova remnants taken by X-ray astronomy satellites and other telescopes.

(4) Computer simulation of supernova explosion: This part shows the beginning of a supernova explosion. Visualized in this part is a computer simulation of the explosion.

(5) Visualization of ASTRO-H, aka Next(New exploration X-ray Telescope): ASTRO-H is the new Japanese X-ray astronomy satellite following “Suzaku”.

3. Science Data

In the astronomical episode, we used “Suzaku” shape data and the millennium of the supernova of AD1006. In the image gallery, we used all-sky maps and images of supernova remnants. In the simulation part, we used simulation data of supernova explosion.

- Shape data of “Suzaku” to visualize the satellite: Three-dimensional shape data of the outside of “Suzaku” are offered by Japan Aerospace Exploration Agency. Shape data of the inside are created from publicized plans of “Suzaku” [1] and [2].
- Millennium of the supernova of AD 1006: “Suzaku” took pictures of the millennium of SN 1006 [3].
- All sky maps at visible wavelengths: Hipparcos Catalogues, 1997, ESA SP-1200 [4] are used to create the starry sky at the beginning of the image gallery.
- All sky map in X-rays: Used in this movie are ROSAT All Sky Survey Diffuse X-Ray Background data 1, 4 and 7 from Max-Planck-Institut für extraterrestrische Physik via SkyView Virtual Observatory [5]. The ROSAT All Sky Survey has revealed the dynamism of the Universe.
- A variety of supernova remnants in several wavelengths: Pictures of supernova remnants are selected from NASA Web sites [6]. These huge data are very important properties for the progress of the science.
- Supernova explosion: The simulation data of a supernova explosion is offered by W. Iwakami and K. Kotake [7]. The data represents the first 0.5 seconds of the process of the explosion at intervals of one millisecond.

4. Highlights

In the historical episode, we visualized the fly-through of Heian-kyo with fine three-dimensional modeling, using about 100,000 polygons and high-quality rendering.

We used the keyword “Suzaku” which represents:

- Suzaku-mon, the main gate of the imperial palaces(Fig. 1),
- The name of the bird guardian of the South (Fig. 2), which is one of four astrological symbols,
- X-ray astronomy satellite (Fig. 3).

These objects appear in sequence between the historical episode and the astronomical part.

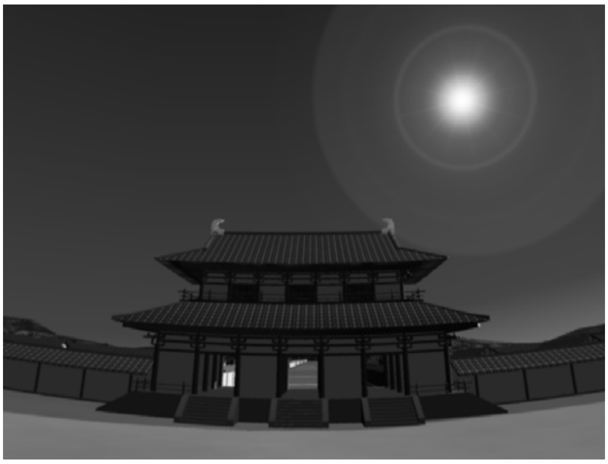

Fig. 1. Suzaku-mon (main gate of the imperial palaces) and the supernova of AD 1006.

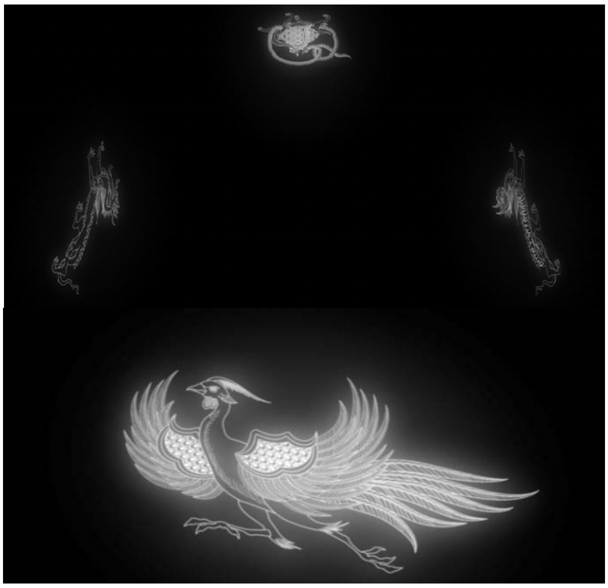

Fig. 2. Suzaku, bird guardian of the South, and other guardians.

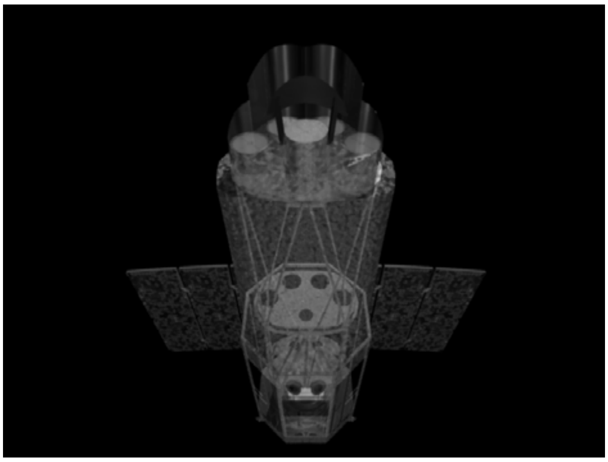

Fig. 3. X-ray astronomy satellite “Suzaku”

In the image gallery, we laid out pictures of supernova remnants (Fig. 4). As for pictures in X-rays, we used many Chandra’s high-resolution data. The Chandra X-ray Observatory has been NASA’s flagship mission for X-ray astronomy, i.e., Chandra is designed to observe X-rays from high-energy regions of the Universe.

Next part shows a typical figure of the inner structure of a red giant star just before the explosion (Fig. 5) and the visualization of the very beginning of a supernova explosion using data of a computer simulation (Fig. 6). To visualize the explosion, we use the volume rendering function of POV-ray (Fig. 7) together with iso-entropy surfaces (Fig. 8), cross sections (Fig. 9) and so on.

In the ASTRO-H part, we have created a 3D model based on public images [8] to visualize the forthcoming ASTRO-H in orbit (Fig. 10). The research in astronomy will continue from now on.

5. Conclusion

Through the production, we have got several achievements;

- Fly-through part: So much time for modeling and rendering results in a good quality.
- Computer simulation part: We have learned how to visualize invisible processes.

The students would like to thank teachers and other members of the Science Image Creator Course for many advices and encouragements. We also would like to thank Honami SUGIOKA for the excellent narration.

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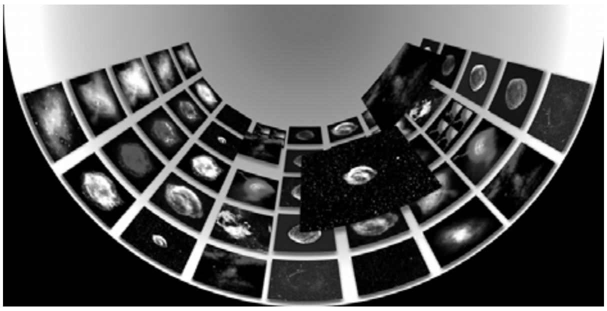


Fig. 4. Image gallery (dome master)

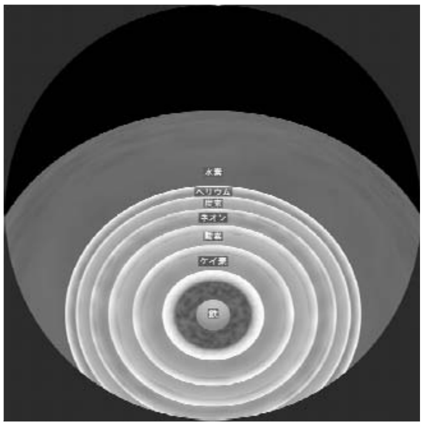


Fig. 5. Inner structure of red giant star just before the explosion (not scaled)

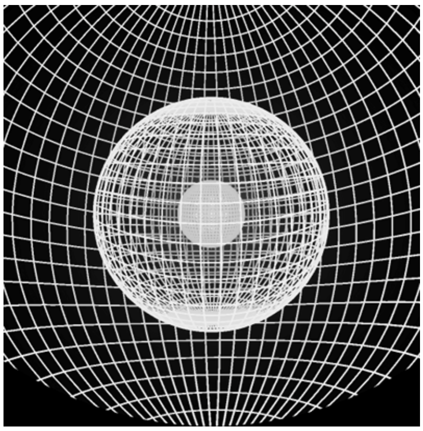


Fig. 6. Simulation grids (subsampled)

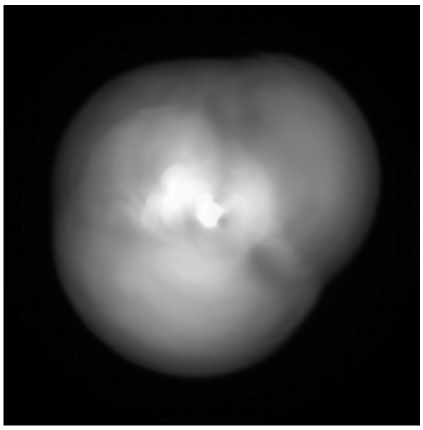


Fig. 7. Volume rendering of simulation data

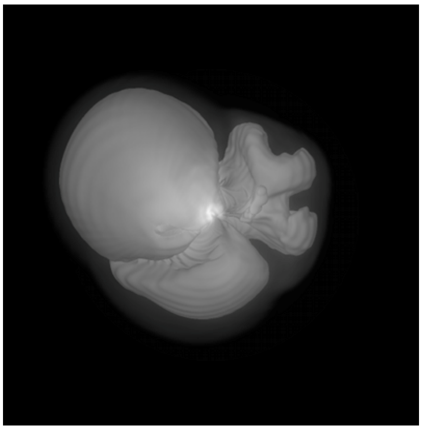


Fig. 8. Iso-entropy surfaces superimposed on volume rendering

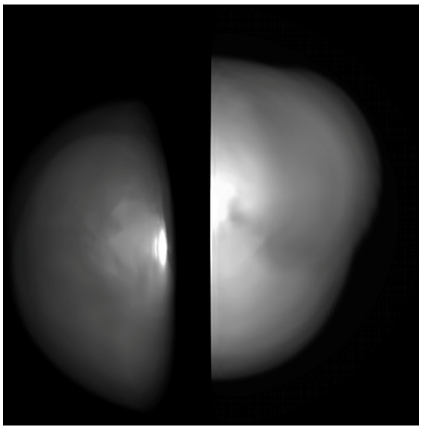


Fig. 9. Cross sections

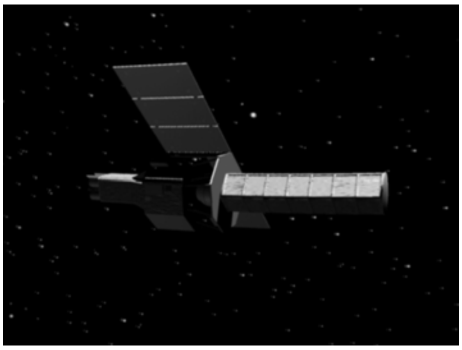


Fig. 10. ASTRO-H in orbit

Visualize the reconstruction of early embryonic zebrafish

Hitoshi Miura*

This paper describes the process of visualizing the early embryonic zebrafish (Danio rerio). The data sets includes the xyz positions of each cell's nuclei in the egg according with developing the early stage of embryonic cells of post fertilization. Digital scanned laser light sheet fluorescence microscopy (DSLM) was used in acquiring the data.

1. Introduction

In developmental biology, zebrafish (Danio rerio) is one of a model system such as Caenorhabditis elegans and fruit fly. One of the features of using zebrafish is that it grows quickly after fertilization. It takes several days from post fertilization to the hatching. Also its egg part is almost transparent. Thus the observation is easy during the embryonic development.

In 2008, Philipp et al at European Molecular Biology Laboratory (EMBL) achieved the reconstruction of early embryonic zebrafish, i.e. "digital embryo" by using Digital scanned laser light sheet fluorescence microscopy (DSLM) [1] [2].

They recorded the nuclei of the 16,000 cells of an 18-hourold zebrafish embryo, a volume of 1000 cubic micro meter at every 60 second. The resulting resolution of the image pixels was at least 1500 by 1500 to the x-y plane and step size along the z axis was 3 micro meter[1].

In the end of 2008, the author has acquired the deconvolved data, based on this result by the cooperation of Philipp et.al.. Thus the project to visualize the data in 4 dimensional space time with x y z t started since then.

2. Digital scanned laser light sheet fluorescence microscopy (DSLM)

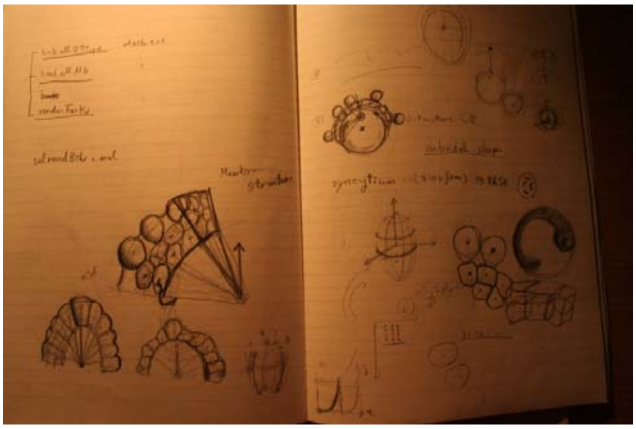
Digital scanned laser light sheet fluorescence microscopy was introduced by Ernst H.K. Stelzer et. al. at EMBL in order to observe the microscopic organs in vivo. The concept behind DSLM is to generate a light sheet with a laser scanner that rapidly moves a micrometer-thin beam of laser light vertically and horizontally. Nuclei in organs were labeled at the one-cell stage by mRNA, with the result the enhanced green fluorescent protein (GFP) localizes to chromatin [1] [3]. The excitation light sheet is used efficiently to achieve optical sectioning. As the result, photodamage which arises in large samples in observing in vivo is reduced [4].

3.Visualization process

The data provided by Philipp et al. at EMBL were series of x y z position of each nuclei along the time from 1 to 900 min.

The number of the nuclei in the embryo is 68 at the starting point and 15,072 at the ending point. The data also included the size of the bounding boxes along the x, y, and z axis.

Each bounding box showed the size of a nucleus by the deconvolution of the images produced with the DSLM.



. Fig. 1 Pre visualized work. Idea sketches for visualization on the author's notebook.

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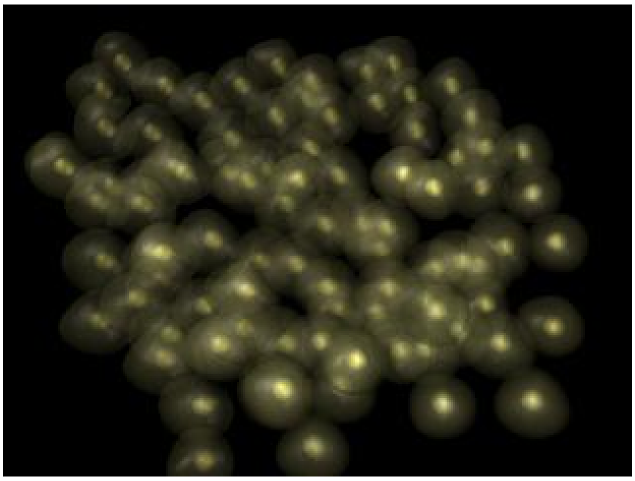

Fig. 2. Test view with the membranes of each cell. On the other hand, yolk sac does not appear in this computer drawing.

However, there is no information of membranes of each cell. There is no information of a yolk sac membrane which covers all cells and unifies the whole egg as well.

If there were no membranes of the cells and no yolk sac in the resulting visualized images, it is difficult to understand what was visualized by the image, because it showed merely a set consisting in many nuclei with a rugby ball shape(Fig. 2).

Thus the membranes of a yolk sac and each cell were added in visualizing process.

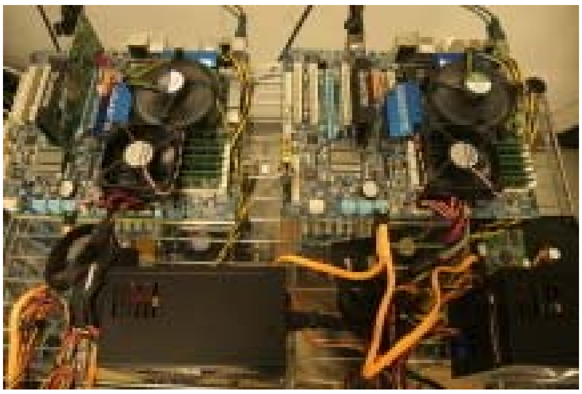

Fig. 3. The hardware environment. Upper side shows two core i7 940 PCs , the lower side shows two core 2 quad PCs.

The size of the membranes of each cells were calculated below; The typical mean ratio R(t) between cell size and nucleus size were assumed 5.0 at t=1, 2.5 at t=270, and 2.0 at t=900. Adding 10% randomness to the R(t), the cell membrane size were defined by multiplying R(t) to the size of each nucleus.

On the other hand, the systematical determination of the size of a yolk sac membrane might be difficult. The shape of yolk sac move constantly and drift its center dynamically in vivo.

In this visualizing work, the shape of a yolk were assumed as a anisotropic scaled sphere, and its size were adjusted manually in order to fitting the cells through the process(Fig. 4, Fig. 5).

This procedure might not be perfect and might not be the best solution. However, here is the issue of the "direction" or "stage effect" when we interpret data and realize the image by translating numeric data in the abstract world into the visible concrete image world.

Because the membranes were shown as faintly as possible in this movie, they do not prevent from observing the nuclei behaviors which were based on the result of deconvolved DSLM data. As a result, the visible reality of the movie might be compatible with the scientific reality.

4. Hardware Environment

The two sets of core i7 940 CPU PC with 12GB DDR3 1333 memory and the two sets of core 2 quad 9550 CPU PC with 8GB DDR2 800 memory were assembled to enlarge the rendering power (Fig.3). The typical rendering time of the stereoscopic scene for 1 min needs approximately one week.

5. Results

The resulting movie was made in order to appear on the stereoscopic projection system, which has been developed in the 4 dimensional digital universe (4D2U) project [5].

The movie has 2 min duration. By making the movie in the 4 dimensional space time that is x y z

Fig. 4. The rendered image with membranes of nuclei and yolk sac. The small bright points show the nuclei of the computer rendering image. The number of nuclei is 68 at t=1.

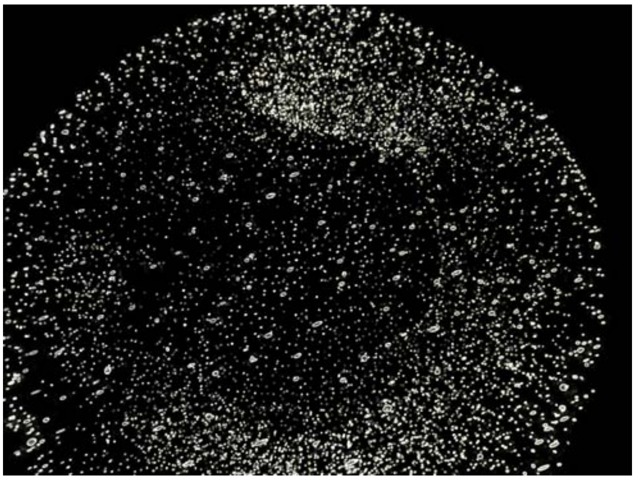

Fig. 6. The rendered image with membranes of nuclei and yolk sac. The number of nuclei is 15,349 at t=900 The size of nuclei tends to be smaller. The outline of nuclei was emphasized for printing the paper

Fig. 5 The rendered image with membranes of nuclei and yolk sac. The number of nuclei is 7,736 at t=300. The vertebral structure starts to be seen.

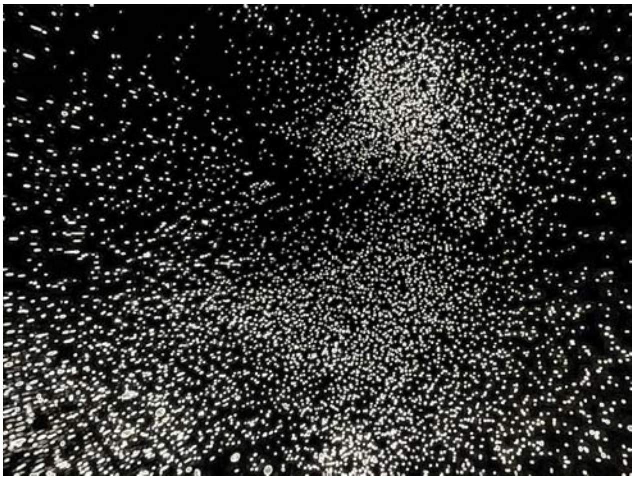

Fig. 7. The rendered image with membranes of nuclei and yolk sac. The number of nuclei is 12,212 at t=400 The stereoscopic cameras had been into the inside of the yolk sac. The lump of nuclei at the right top of the image starts to form the cephalic part of the embryo. The outline of nuclei was emphasized for printing the paper.

t space, it acquires much more free camera work.

The cameras go into the yolk sac, and the audience could see the process of the fission of nuclei. The scene might be analogous to the stars in the universe. Adding to this, adopting the stereoscopic movie could give easy recognition of the depth along the z axis. The position of each nucleus in 3 dimensional space can be clearly identified.

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The author deeply thanks Philipp J. Keller who has accomplished the pioneer works to get embryonic zebrafish data by using digital scanned laser light sheet fluorescence microscopy and provide the precious data in order to make 4D movies. The author also offers my thanks to Karoji Hiroshi in National Astronomical Observatory of Japan (NAOJ), and Nagayama Kuniaki in National Institute for Physiological Sciences (NIPS), who guided me to make this visualizing work. Ueno Naoto, and Nonaka Shigenori in National Institute for Basic Biology (NIBB) always gave a lot of useful comments in biological viewpoints. Takeda Takaaki and Hayashi Mituru in NAOJ helped me in making and testing the stereoscopic movie. This visualizing work was supported by Inter-institutional research cooperation of NINS "Imaging Science" project.

"HAYABUSA Back To The Earth"

Hiromitsu Kohsaka[*1], Ohmi Iiyama[*2], Isshi Tabe[*3] and Makoto Yoshikawa[*4]

Hayabusa spacecraft was launched on 9 May 2003. After a period of reconnaissance operation, the spacecraft left the home position and made tours to various altitudes and solar phase angles to access the polar regions of Asteroid Itokawa. A sampling location on a smooth terrain called Muses Sea was selected. The touchdown, the 30-min stay on the asteroid surface, and the liftoff were performed on 19 and 25 November. HAYABUSA is now under preparations for its return trip to the Earth in 2010. This movie is the one of the document focused upon the eventual and dramatic round trip of Hayabusa spacecraft by using sophisticated computer graphic technologies.

1. Introduction

This movie describes the mission of Spacecraft Hayabusa. When the planning of this movie started, we decided that this movie should not be just an introduction of the mission. This is because we believe that space exploration, such as Hayabusa mission, is based on the natural desire of human beings. we consider what makes human to go to the universe is the desire to know what we are, and the scientific objectives of Hayabusa, that is, to know the origin of the solar system, are connected to this desire. We are happy if you feel the universe with Hayabusa when you see this movie. Before making this movie, we took part in making a video called "Inori". This is also the story of Hayabusa mission and it was made by JAXA. At that time we made CG models of Hayabusa and Itokawa, and they are quite useful for our new movie. Of course, we have modified the CG models, and the quality of the models became much better.

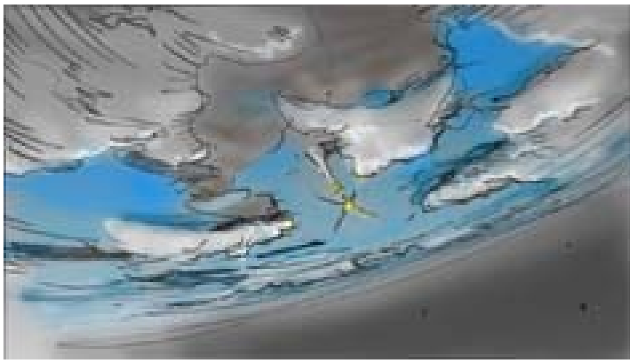

Fig. 1. Scene of launch of Hayabusa view from space.

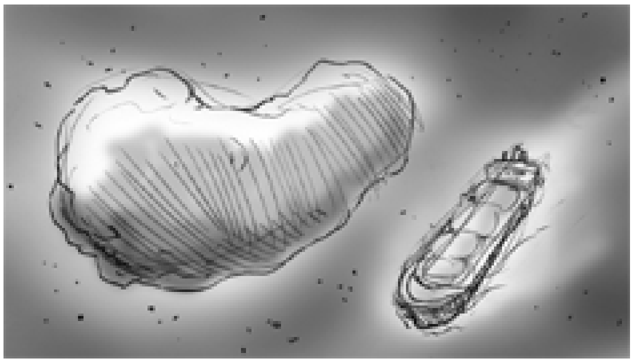

Fig.2. Itokawa and the largest tanker. Thie comparison is good example to give right conception about size of characteristic asteroid.

2. Featured New Technics

At first, we made the concept sketch. Before considering the structure and story of this movie, we made images of some scenes which characterize this movie. And then, we moved on to the scenario, and storyboard.

In Fig.1.2.3and 4 we show the basic idea for each scenes. The scene of launch of rocket is very

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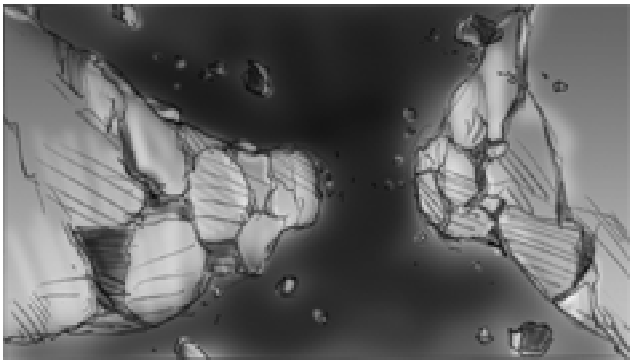


Fig.3. Inside structure of asteroid Itokawa. This is just imaginary, but it can be.

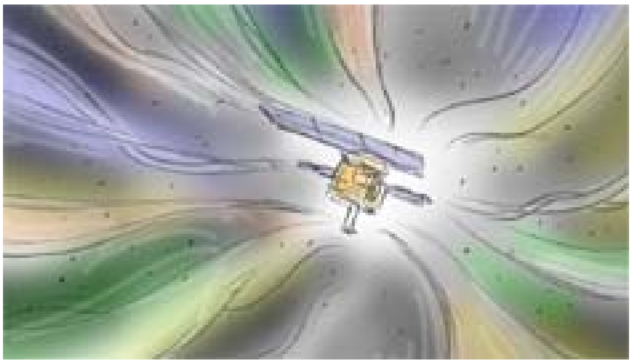


Fig.4. An example of the recollection scene. When the communication is cut off, personified Hayabusa and audience are recollecting half his

popular, but ordinary. If set the viewpoint in space, we can see the brighter light point from the earth becomes shape of spacecraft. Fig.2 shows the spatial size of Itokawa compared with size of the largest tanker.People understand easily about characteristic size of asteroids. Fig.3 shows inside of Itokawa by cuts it in the right in two. We know that there are many void space between the rocks. The mass of Itokawa is too light conspicuously to expect from its size. Because nobody knows the inside structure of rocks of Itokawa, we made the imaginary structure but it can be. Fig.4 is an example of the recollection scene. When the communication is cut off, personified Hayabusa and audience are recollecting half his life. This scene is one of the climax of this movie.

When the idea is all present, we made the outline of storyboard. But after this, we use a little different method. That is the method of “animatics”. We make whole movie first by using low quality, simple images. Although the quality is low, the timing and the angle of the camera are the same as the final version. This means the amimatics is previsualization techinc and we can observe whole movie before high quality rendering will be done. We put narration in this animatic. Then the narrator is one of the authors H.Kohsaka. By this method, we can have the common view of the final work from the beginning. This is a sophisticated method for movie making, because we can always check the good points as well as problems in the work. In this workflow, the animatic will be updated to the final work automatically as the works of CG is going on. We were able to make the movie very efficiently, because we could always check the each scene in the whole sequence. The actual projection to the dome of planetarium was also done by using the movie of animatic. Checking the special effects on the dome projection, we were able to change the angle of camera and make the animation. We employ two domes, Katsushika City Museum and the Science Museum of Tokyo.

3. Special Techinic for dome environment

The space of dome is quiet interesting from the point of movie making. Since we are familiar with using the flat display such as TV, we felt that the dome space is quite new media. The feature of the dome is that it can show the images of all the directions at the same time, and we consider there are two customs. When an object is shown at the top of the dome, we feel pressure and heavy weight. In the scene like as an upper panel of Fig.5, we express the massive weightiness of the object by appearing it from the top of the dome. The most effective scene is the departure at the beginning shown in Fig.1. The earth is emerging over our head and coming toward to us. We think that the hugeness and the mass of the earth can be expressed well. The next is the case that an object is appear in lower part of screen like as the lower panel of Fig.5. In this case, we feel “falling down.” However this effect is rather big, when the dome is tilted, in the case of “flat floor theater” we can feel the effect sufficiently. In our movie, such effect is seen when Hayabusa is going down to Itokawa.

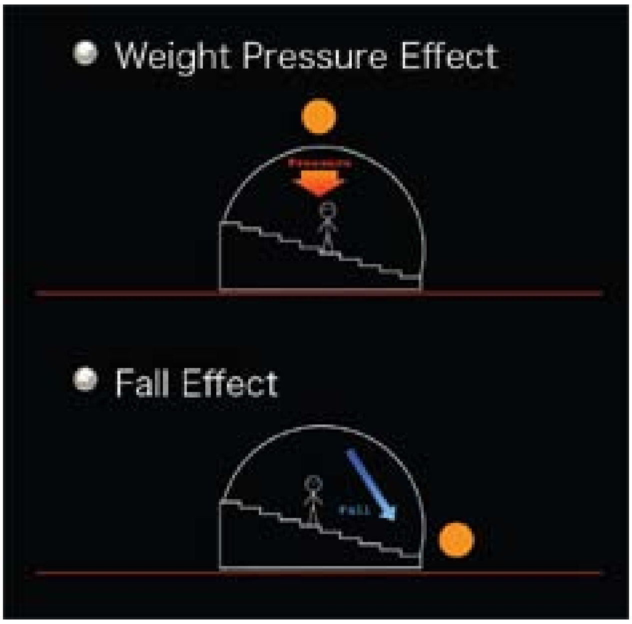


Fig.5. Weight Pressure Effect(upper panel) and Fall Effect(lower panel). These effects are peculiarity in dome environment.

4. Narration and Music

Narration and Music are also important item for the perfection of the movie work. We assumed the narration of this movie to late Ken Ogata, who is the very famous actor of Japan. However, we heard the sad news in October last year while we were negotiating. He passed away suddenly.

At last we decided the narrator of this movie to Saburo Shinoda, who is also famous actor especially for the role of Ultra-man Taro. The voice of Shinoda has the feeling of peacefulness and gentleness, and we think that the concern for Hayabusa is expressed quite well.

Fig.6. A portrait of Saburo Shinoda whose voice is very peaceful and gentle.

All the music is custom-designed. We had many meeting with the composer and the musical director to discuss elaborately, as a result the music becomes very nice to express the fine nuance of the images. In the epilogue, we inserted a singing of female singer. The song is made by composer Yoshihisa Sakai and lyrics by H.Kohsaka.

5. Conclusion

There is two kinds of final work, one is detailed version of 43 minutes, and the other is basic version of 26 minutes. As a creator of this movie, we do hope that you will watch the full version of 43 minutes.

The authors hope to ask you what do you think is the most important thing to make good movie work. It is not the power of CPU. It is not the cost of production, either. We conclude taht the most important thing is to make the staff members highly motivated and incentive to do the work. The most important thing in creating movies is the individual members. If the stuff members are the highly motivated, the quality of the results becomes high. We felt this strongly through the work of this movie making. In Japan, the copyright of image creators is not respected sometimes, and we are afraid that such trend discourages the stuff members. We think we should work for this problem from now on. We feel the limitless possibilities in the images projected on the dome. If you have a plan for the full-dome image, please contact us. Let's make nice movies together.

You can see more info about Hayabusa movie in web-site(in Japanese) http://hayabusa-movie.jp/.

The SUN

Yuma Watanabe*, Masaru Hirohashi,
Masanori Iuchi, Mai Yonezu
Creation Advisers: Yukio Ando, Hitoshi Miura

1. Introduction

Our movie's theme is "The Sun" and it features original ambient music played to a stylized collage-like movie.

2. Concept

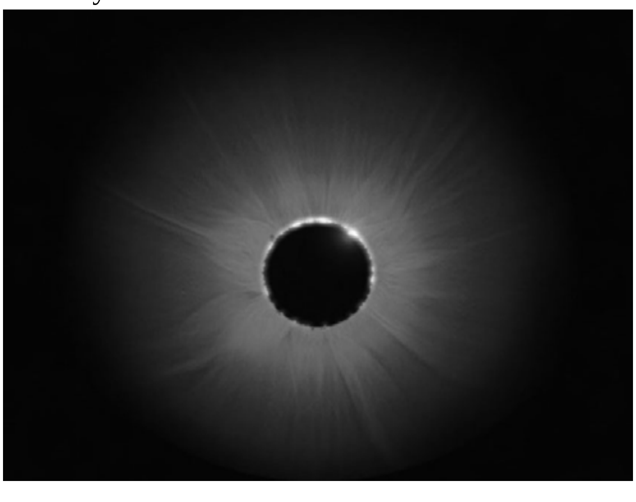
The scenes are based on images of the sun drawings in the Middle Ages, as well as pictures of the solar eclipse, and visualization of the solar magnetic field lines. [taken by NASA/ESA's SOHO and JAXA's Hinode spacecrafts.]

3. Scenes

We, four creators each made different scenes of the sun complemented by ambient music made by team members Yuma Watanabe and Mai Yonezu.

4. Tools

The visual tools we used to produce this movie include Maya, 3ds Max, Adobe Photoshop, After Effects and Premiere, and the musical tools we used here include Yamaha Motif and Pro Tools, Audacity.



5. Features

We edited the movie in such a way that it's not similar to conventional science documentaries.

One of the biggest reasons why we made this movie is to try to increase the number of people who might come to enjoy scientific films.

We would like to continue to make various scientific short films in the near future.

*Yuma Watanabe site→(http://www.ai2.asia)

"What do the Incan Constellations tell us?" The Views of Anthropology and Astronomy in a Planetarium Session

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Isshi TABE[6], Kaoru KIMURA[7], Seiichi SAKAMOTO[1,2]

Science communication is becoming a familiar way to promote science. However this is often not very effective for people who dislike science. So to overcome this, we have developed a new way to interest these people in science. Instead of talking directly about science, we interest them using ancient mythological stories about the night sky. In our planetarium session, we introduce dark clouds in the Milky Way, starting with a story about how, in Incan folklore, the shapes of these clouds signified animals. Then we explain that more recent research has shown that these clouds are the cradles of newborn stars. Our goal is to present things in a way that is interesting to a wide range of people, from anthropologists to astronomers, and everybody in between.

1. INTRODUCTION

The principle aim of science communication is to share the fun and the importance of scientific research with non-scientists. Science communication events have become very common recently (e.g. science cafes). However, a serious problem that has not been addressed by recent science communication activities is that almost all participants are people who are already interested in science, and the organizers do not have the resources to accommodate non-scientists, or to encourage them to come to the events. That is to say, most science communication is typically only aimed at people who are already interested in science, and is not effective for those who are not interested in science. There are several reasons why it is not effective. One of the reasons is that science communication events usually only focus on science, which is intimidating to those who do not like science.

When we say ‘research’, it does not only mean scientific research but also cultural research. These two different fields fascinate different types of people; those who are, and those who are not interested in science, culture or both. Thus we should not focus on science alone and do science communication. When we find a common topic between the two subjects, we can invite both groups of people who are interested in these respective subjects, to science communication events. Then a new way of communication can be introduced that links the two subjects. In this way, science communicators are shown the point of view of a field that is not their specialty and vice versa. This could facilitate new avenues of research in both fields.

We have developed a new type of planetarium session that is designed to achieve this goal. Usually in Japan, a planetarium session is typically about Greek constellations and myths but has no science. So we decided to combine astronomical myths and science in a planetarium session. This includes an anthropological view of astronomy that is probably new to most people, including scientists, which should make them realize that ancient cultures were fascinating, and that what we see in the modern world is but one of a string of historical perspectives.

2. METHOD

2.1 A Common Thing Between Anthropology and Astronomy

The first thing that we did was to try to find things in common between Anthropology and Astronomy. Fortunately, we found that the Incan civilization had a unique culture which we could connect to astronomy.

Because the Incan civilization was in the southern hemisphere, the Incan people were able to see the Galactic center high up in the night sky. In figure 1, we can see there are many dark areas in the Milky Way. These dark areas are the focus of our planetarium session.

In the session, we talk about these dark areas from

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4 National Astronomical Observatory of Japan, Japan
5 National Museum of Ethnology, Japan
6 Libra Corporation, Japan
7 Japan Science Foundation, Japan

Figure 1. The Milky Way seen from the southern hemisphere.

Figure 2. Herschel's Milky Way [3].

the point of view of anthropology at the first, and then from the point of view of astronomy. This order gradually leads people who are not interested in astronomy or science, but who do like myths and folklore, into listening to scientific topics and visa versa.

We will show how we explain the dark areas from these two points of view in our planetarium session in this section.

2.2 Anthropology of Dark Area in the Milky Way

About 500 years ago, the Incan civilization was prosperous in a place called Cusco (at lat. 13° S) in South America. This is the home of the potato plant. The Incan society was very affluent and history claims that their people never starved.

In common with many well-known ancient people, Incan people used the stars to judge their agricultural life. For example, when they could clearly see a constellation called "Collca" (aka Pleiades), this meant that they would have a good harvest [1].

They did not only use stars, but also dark areas in the Milky Way for making constellations [2]. For example, they called the Coal Sack the "Quail". This is a new point of view from the perspective of those of us who live in the northern hemisphere, and this is one of the most interesting things in Incan anthropology. These constellations reflected Incan human relations; namely, each family had its own representative animal and they followed the relationships or rules of their designated animal.

The dark area constellations had myths as well but their myths were closer to folklore, unlike Greek myths. The "Quail" was a symbol of the dry season, because they thought that quails were always hungry and never became full, though kept eating food. Another constellation, the "Fox", meant greediness and the origin of farming. A fox cheated a condor into flying to a banquet in heaven. At the banquet, the fox ate and ate and ate heartily. On the way back to the ground with the condor, the fox insulted the banquet, even after having eaten lots of food there. So the condor got angry and dropped the fox down to the land from the sky. Then the stomach of the fox exploded and all of the food that he had eaten, was spread around, and created agriculture.

In the planetarium session, we present these interesting stories of the Incan people, to fascinate the audiences, and then move on to astronomical topics.

2.3 Astronomy of a Dark Area in the Milky Way

At the very beginning, astronomers thought that the dark areas in the Milky Way were holes or windows in the night sky. For example, over 200 years ago, Herschel drew an image of the Milky Way, which is shown in figure 2, which had a slit in the right side [3]. This slit indicated that there was nothing in that area, that is to say, a hole in the sky.

Astronomers believed in Herschel's Milky Way for a long time. However Barnard disproved this faith. With improved instruments, he started to observe the dark areas photographically [4]. He deduced that they were not holes, but were actually something in between the earth and the stars of the Milky Way, since he saw that the edges of the dark areas were silhouetted and that some very bright stars could be seen dimly through the dark areas. So, he named these "dark clouds".

The most important point here is that we try to explain science as a historical story, starting from "what was the mystery?", "how could one answer this question?" and "how could one interpret the result?", namely, hypothesis, method, result and discussion. If instead we were to talk about recent research directly, then audiences probably would suddenly feel intimidated and get bored and tired. We avoid this by showing how scientist's thought things through step by step.

We also present another example of this method. After Barnard and other astronomers started to claim that the dark areas were the actual objects, Trumpler did an experiment. He tried to estimate the distances of stars in the dark areas using two methods, a geometrical way and a measurement based on the brightness of stars. However the two results came out differently and he found that if he assumed that the stars had approximately one magnitude of extinction, then this difference could be explained. Therefore, finally, he concluded that there were some dark objects interrupting the stars' light [5,6].

In this case, the hypothesis was 'if the dark areas are objects', the method was 'the measurement of the distance of the stars using two completely different ways', the result was 'the two results do not agree', and the discussion was 'the dark objects cause the dark areas'. We try to show science as a historical story and try to trick people who are not interested in science into science.

At the end, of course, we introduce recent astronomical research about the dark clouds and what will happen in astronomy in the near future. In the last 50 years, observations with other wavelengths have become possible and the dark clouds have been revealed to be cradles of newborn stars. However this is still not completely understood. So astronomers are building larger, more sensitive and higher quality telescopes in many places of the world and in the space. One of these areas is in the Andes mountains of the Atacama desert in Chile, where about 500 years ago, the Incan people ruled. In this place the folklore of the local people, and modern astronomy still share the sky.

3. BROADCASTING AND FUTURE WORK

This planetarium session is still a work in progress. We plan to give a talk or a preview of the session in the Japan Planetarium Association (JPA) on June 2009. Then we will start to negotiate with the museums that are interested in broadcasting this session. This session will be distributed for free.

4. CONCLUSION

Although we have yet to show this planetarium session to the general public, we are hopeful that the approach that we have developed will bring more people into an appreciation of anthropology, astronomy and science in general. In the future we can then expand into other areas, bridging the divide between those who look towards the past for inspiration, and those who look to the future.

ACKNOWLEGEMENT

We thank The Graduate University for Advanced Studies for supporting this project. The ideas in this session were inspired by an anthropologist Hideo Kimura (The Univ. of Tokyo). We all appreciate his help.

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My first experience of CG movie creation "Telescope - The Door to The Universe"

Masaru Hirohashi [*1]

A short movie to boost The International Year of Astronomy 2009. It tells the history of telescopes over the last 400 years. Originally it was made In NTSC DV format, I am converting this short movie into dome master for planetarium theaters. Furthermore, I am going to release a 20 minute planetarium show this spring.

1. Introduction

First of all, I will introduce my biographic outline. My name is Masaru Hirohashi. I was born in 1964. Living near Mitaka. I have twin sons aged 4. I work at home while looking after the kids.

I was engaged in planetarium program production for over 10 years at Konica Minolta Planetarium. Since the 1990s, I have been keeping a close eye on the digitalization of the planetarium industry.

Originally I am not a creator but a producer, but I've established myself as a freelancer for creating myself fulldome digital contents.

2. In a digital planetarium research facility

Before introducing my movie, let me talk about the old times. I worked at Minolta Toyokawa factory from 1992 to 2003. In a way, that factory was a digital planetarium research facility.

Key persons of the planetarium industry from U.S.A. often visited our factory and introduced new systems and new format shows. Like Mr. Steven Savage and Mr. Terence Murtagh.

I learned a lot of things there, and I created many show programs blending star projector and digital projectors. That was an extremely valuable experience.

3. Participating in IPS conferences

Participating in IPS conferences always built up my enthusiasm for digital planetariums.

In 1994 Osaka. At a post conference tour in Minolta factory, we released the world's first combined show “Powers of The Universe”.

In 1998 London. Fulldome system StarRider & SkyVision made their first appearance. I was really moved.

In 2006 Melbourne. I was impressed with the presentations of Uniview by Dr. Carter Emmert. That’s exactly the time I decided to dedicate my life to create dome contents.

4. Learning a skill of 3DCG

So I left the company to concentrate on learning 3DCG creation skills last year.

Technical college of Computer Graphics, Science Image Creators Course of Science Culture Promotion Unit through Astronomy Image by NAOJ, and personal coaching by my friend Mark Aldred living in Japan, creating dome contents for ten years.

And also Mr.KAGAYA, Mr. Kohsaka(LiVE) and Mr.Nakayama(NAOJ), today’s presenters, they gave me valuable advice and encouragement as CG experts.

5. The Process of making “Telescope”

Now I'll explain the process of making the movie, “Telescope – The Door to The Universe “
It’s originally my college graduation work and it’s my first computer graphic movie.

- Now, what should I make?
- Of course , astronomy !
- What kind of theme?
- Next year 2009 is IYA memorial year.

So, I will make a short movie about 400 years history of telescopes and astronomy , as a promotion for IYA 2009.

6. The concept of “Telescope”

The concept of “Telescope – the door to the universe “ is very simple.

In this movie, Telescope is a kind of Time tunnel. The movie features camera passes through 400 years history of Telescope as if it were one continuous shot. Please enjoy.　(Play the movie)

7. The promotion of “Telescope”

Did you enjoy my first solo movie? Now I will talk about my plan to promote my work this year.

I already put this short movie on YouTube site. And I give it for free to science museums, planetariums theaters and other education facilities.

And now I am making 20 minutes planetarium show. This show is going to be authorized as an IYA selection product.

And also I am planning to convert it into full dome format.

8. Conclusion

Lastly, let me talk about my vision.

- I’d like to make a contribution to the transmission of science images from Japan to the world living near this Mitaka obsevatory.
- To carry out the vision, I need co-workers who have the same aspirations.
- And I’d like to continue creating contents that promote interest in science

I hope you enjoyed my presentations. Thank you for your attention

Fig.1. The flyer of“Telescope – the door to the universe “ 20 minutes planetarium show.

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Production of a dome movie "The Celestial Railroad" and our future approach

Yutaka Kagaya [*1]

This is a report regarding a dome show “The Celestial Railroad” produced by KAGAYA Studio, which is focused on the process of production and the status of distribution for two and a half years since its release. Furthermore, you will see our approach to a new project to promote the use of the dome movie as an educational material at school. New techniques currently being tested and studied at KAGAYA Studio are also introduced.

1. Introduction

The dome movie “The Celestial Railroad” produced by KAGAYA Studio was released in 2006. It has been presented in more than 40 theaters and attracted 600,000 audiences. Let me tell you about how we came to produce this movie and what our future approach is.

2. How we came to produce this movie

As an artist, KAGAYA, I have been approaching to inspire people’s interest in the universe, using art techniques and producing many works themed on the universe. The artworks and illustrations related to the universe have been used for many books on astronomy. At the same time, the designs and images themed on the constellations, which appeal to the general public, have been used for jigsaw puzzles. I would like to keep on providing chances for more and more people to be interested in the universe, through the artworks using various media.

One of the reasons why KAGAYA originally came to have a strong interest in astronomy and art is a book titled “Night on the Milky Way Train” written by Kenji Miyazawa. I happened to find the book when I was an elementary school student. Since then, my interest in the world of “Night on the Milky Way Train” has never gone away. I strongly wished to experience the fantasy world of “Night on the Milky Way Train” as real, and it became the driving force behind the production of the dome movie “The Celestial Railroad.” I believed that a dome theater is the best place for audiences to see “The Celestial Railroad” which depicts a fantasy world, and we devoted 3 years to produce the dome movie based on

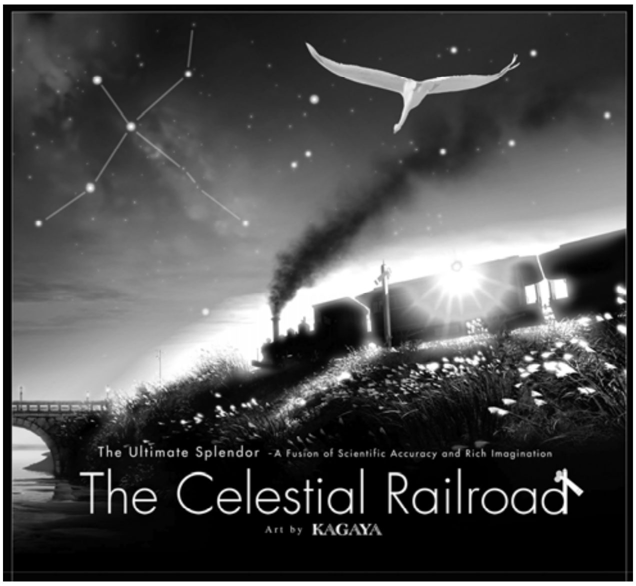

Fig.1. Main visual of “The Celestial Railroad” for worldwide distribution

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Fig.2. Design sketch of the train modeled on trains actually used when the original story was written.

Fig.3. Snap shot of Presentation at Planetarium of Eugenides Foundation in Greece

detailed researches. If you make a dome movie with full CG in the usual manner, you need enormous time and expenses for calculation for computer graphics. However, we could make this dome movie at very low cost with a simple device: distributed rendering system using 24 standard or rather cheap personal computers.

3. Regarding our future approach related to “The Celestial Railroad”

We believe that the movie "The Celestial Railroad" can be a practical and effective comprehensive educational material which covers not only astronomy but also literature, geography, art and music.

KAGAYA Studio has started to create Teacher’s Guide for “The Celestial Railroad” so as to increase the possibility of the dome movie to be used as an educational material. For teachers, we will provide a Teacher’s Guide which has detailed instructions and

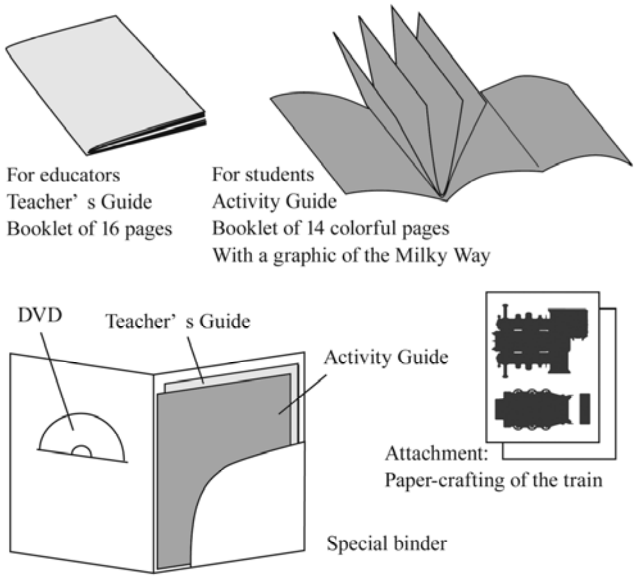

Fig.4. “The Celestial Railroad” kit for educational institutions.

explanations for each subject in order to help teachers conduct a class well. For students, we will provide an Activity Guide which is colorful visual images based. When the Teacher’s Guide and the Activity Guide are available, we would like to present them for consideration to theaters, municipality organizations, educational institutions and astronomical observatories and such.

In addition to this effort, we would like to try to discuss with National Astronomical Observatory and the Ministry of Education, Culture, Sports, Science and Technology so that we can obtain cooperation from them and contribute to this field. At the same time, we would like to make our best effort to create as many opportunities as possible to use a dome movie in the educational field in cooperation with other educational content holders.

4. Regarding Computer Graphic Techniques currently studied for our new projects

KAGAYA Studio is studying and testing various techniques to create new visual images for dome movies. Our main techniques are as follows;

a. Kids Character development

Effect and note when you use a Deformed Character in a dome movie.
Matching rendering in Anime Style to a dome movie.

b. Techniques to nicely depict a sophisticated image of a person in detail in a CG dome movie

3D Modeling made from a statue (It will be effective in case we cannot use CG Modeling.)
A technique to do 3D scanning of an actual person.

c. Documentary Style (combination of Live Footages and Full Dome Computer Graphics)

Fig.5. Deformed Character for children

Fig.6. Statue of the Goddess specially produced (Left) / CG made up from 3D scanning of the statue (Right)

Fig.7. 3D scanning of the shape of an actual person

d. Stereogram

In the near future, we, KAGAYA Studio, would like to present new dome movies using such techniques and the techniques acquired through our experience in the production process of “The Celestial Railroad”.

5. Conclusion

KAGAYA Studio keeps on making efforts to increase the possibility of dome movies, developing the manner how such content will be used as an educational material and developing techniques to create various kinds of dome movies.

For the most up-to-date information, visit KAGAYA Studio’s website.

http://www.kagayastudio.com/

Proc. of the IFSV 2009 in Tokyo

Three-Dimensional Animation by Electro-Holography

Hirotaka NAKAYAMA*, Yasuyuki ICHIHASHI*, Nobuyuki MASUDA*, and Tomoyoshi ITO*, Members

Electroholography is one of the expected techniques for achieving Three-Dimensional (3-D) television. Because holography is one of the methods for reconstruction of 3-D objects. But the amount of calculation is so enormous that the speed-up of calculation is indispensable to achieve the electroholography television. Our laboratory in Chiba University developed the special-purpose computers, named HORN, to generate hologram at high speed. At present, we achieved reproduction of the image of the 3-D object composed of 1,000,000 points in every second.

1. Introduction

In late years 3-D display technology spreads rapidly. And the year 2009 was considered a the 3D first year. Many movie theaters hurry the introduction of the 3-D display system in Japan too.

By the way, there are various systems of 3-D display technology, and many systems use glasses (Table 1).In contrast, because holography is one of the methods for reconstruction of 3-D objects, the glasses are not necessary, and there are few eyestrains.And the electroholography can display a 3-D animation, so the application to the 3-D TV is expected. But the amount of calculation is so enormous that the speed-up of calculation is indispensable to achieve the electroholography television. In our laboratory, we try the improvement of the calculation speed from the side of software and hardware.

Table 1 Various systems of 3-D display technology

stereogram with glasses	anaglyph linearly polarized glasses liquid crystal shutter glasses infitec glasses
stereogram without glasses	parallax barrier lenticular lens
wavefront reconstruction	holography

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2. Computer-generated hologram (CGH)

A basic calculation method of Computer Generated Hologram is shown in equation (1). Iα is intensity of point α in the hologram, Rαj is the distance between the point j in the object and the point α in the hologram, Aj is light intensity on point j, λ is wave length of the reference light, and M is the number of the object points. We calculate the superposition of object light and reference light. If total number of pixels on hologram is N and total number of points which construct the object is M, calculation cost per one CGH is proportional to the product of M and N.

$$I_\alpha = \sum_{j=1}^{M} \frac{A_j}{R_{\alpha j}} \cos \frac{2\pi}{\lambda} R_{\alpha j} \qquad (1)$$

And Fig.1 shows the outline of electro holography. We input the data with a three dimensional coordinate to computer, and convert it into a hologram, and we display it to the electronic display devices such as liquid crystal displays, and the 3-D image is reconstructed by reference light.

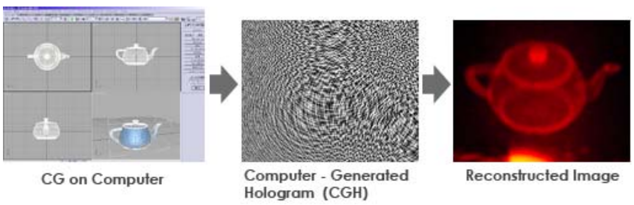


Fig.1 Outline of electroholography.

3. Speed-up by software and hardware

There are some software algorithms to make calculation fast, taylor expansion of square root - fresnel approximation, look-up table of cosine function (Lucente 1993), expression of recurrence formulas (Yoshikawa et al. 2000, Matsushima and Takai 2000, Shimobaba and Ito 2001), and so on.

By using these algorithms, 50 times became faster than the direct calculation(table 2). However, the fast algorithm requires 30 sec per one CGH for 1,408 × 1,050 hologram and 10,000 point object. Video rate (30 frames / s) requires 1,000 times faster, so we have to use special-purpose computer. A special -purpose computer named HORN was developed in our laboratory to handle an object consisting of a lot of points. Fig.2 shows the history of HORN.

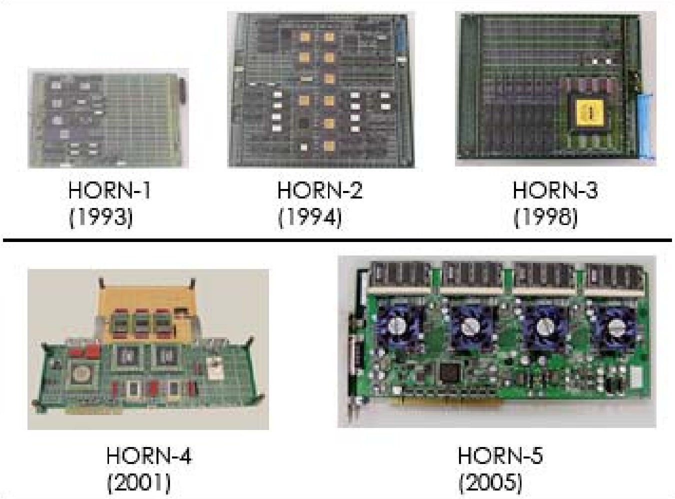


Fig.2 History of special-purpose computer HORN

The high-speed calculation algorithm of the recurrence formula is used for the efficiency improvement of hardware in the HORN-5 board. And the PC for the calculation has HORN-5 board up to four. The host PC is connected to the PCs for calculation with gigabit local area network (LAN) and we use four PCs for the calculation now. And by useing 16 HORN-5 boards, we can display about 100,000 points data in real time.

The latest model number of HORN is 6. We designed and constructed the HORN-6 board to handle an object image consisting of one million points and constructed a cluster system composed of 16 HORN-6 boards. We succeeded in creating a computer-generated hologram of a 3-D image composed of 1,000,000 points at a rate of 1 frame per second by using this HORN-6 cluster system.

Table 2 Software vs. Special-purpose hardware

System (Hologram 1,408×1,050；Object 10,000)			Time/ CGH (sec)	Speed ratio
【Software】 Pentium4 3.2GHz 2GB Memory OS: Linux kernel 2.4.26	Direct calculation algorithm	gcc-O2	1280	0.0178
		icc-O2	1300	0.0175
	Fast algorithm	gcc-O2	24.0	0.950
		icc-O2	22.8	1
【Hardware】 FPGA XC2VP70×4 166MHz	1 HORN-5 board: 1,408 calculations in parallel		0.0679	336
	2 HORN-5 boards: 2,816 calculations in parallel		0.0349	653
	3 HORN-5 boards: 4,224 calculations in parallel		0.0239	954
	4 HORN-5 boards: 5,632 calculations in parallel		0.0185	1230

gcc-O2:GNU C compiler 3.3.2 with optimization option (-O2)
icc-O2:Intel C++ compiler 8.1 with optimization option (-O2)

5. Sample images of electroholography

These holographic models and animations were made by "maya" and "3D studio MAX" which ware 3DCG software. And the hologram is reconstructed in the experimental setup which I showed in figure 3. Images shown in Fig.4 were reconstructed by LED or laser as reference light.

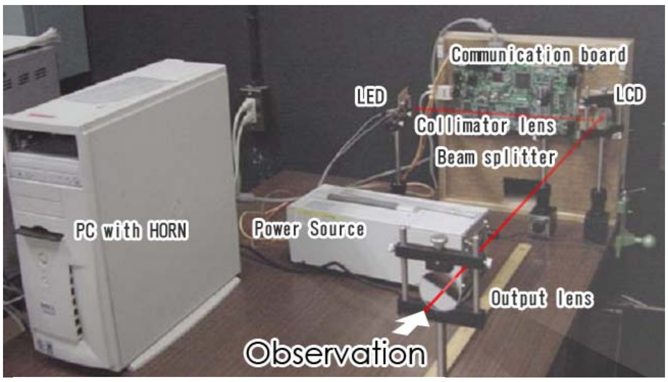
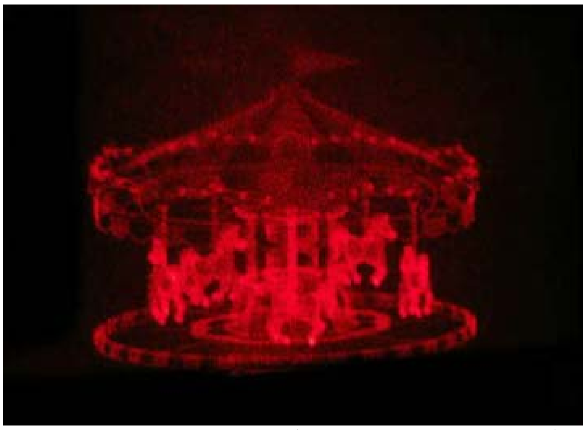


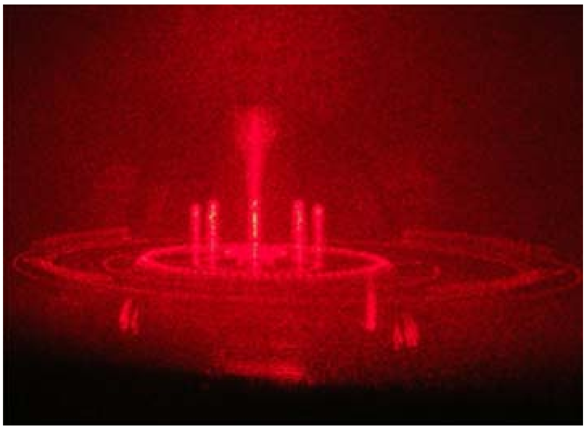
Fig.3 Our experimental setup

a. "Tyrannosaurus" (about 10,000 points)

b. "Chess" (about 50,000 points)



c. "Merry-go-round" (about 100,000 points)



d. "Fountain" (about 1,000,000 points)

Fig.4 Sample images of electroholography
a. Tyrannosaurus / b. Chessboard & chess pieces / c. Merry-go-round / d. Fountain

6. Discussion

We try the improvement of the calculation speed from the side of software and hardware, and the displaying of the object consisting of 1,000,000 points in real-time was enabled. The calculation speed was improved, but there are some problems. For example, it is performance of the display machinery. The improvement of the angle of field is not possible unless the space of the element of the liquid crystal display becomes small. For 3-D TV realization, the development from the various sides is necessary.

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Chapter 3

Dome Theaters

Space Show Production at the American Museum of Natural History

Carter Emmart [*1]

1. Introduction

A decade ago, the millennium project of rebuilding the Hayden Planetarium at the American Museum of Natural History (AMNH) was an opportunity to explore the potentials of what a planetarium could be for the 21st Century. The use of full dome video to tell the stories of the universe through data visualization augmenting the traditional optical mechanical star projection became the goal. Combining these capabilities with a new research department of astrophysics at AMNH allowed productions to highlight in-house research and be guided by astrophysics curators in collaboration with the worlds' astrophysicists. In this way, the new Hayden now housed in the Rose Center for Earth and Space has been able to visualize the most current research in its choice of topics. Distribution of shows has become possible with the growth trend in full dome video in the planetarium market such that Hayden shows are now playing in roughly forty venues worldwide.

In ten years, four 'space shows' have been produced focusing on fundamental topics of the universe: "Passport to the Universe" the debut show focused on the scale of the universe. "The Search for Life: Are We Alone?" looked at the issues of life in the solar system and across the universe. "Cosmic Collisions" addressed the role of collisions in forming much of what we see in the universe, and "Journey to the Stars" examines what stars are why they are important as a fundamental process in the universe and to life on Earth.

2. Precepts

Five fundamental precepts have framed the productions at AMNH, which represent a close working relationship between the departments of astrophysics and education:

Learning Goals: Individual show topics each have their specific goals to be taught in this informal science venue. They are defined at the conception of a show topic and guide the structure of the show and help keep the production process focused.

Accuracy: We are a museum of the known universe. We uphold a public trust to portray the universe to the best that it is currently known, curated in scientific consultation worldwide.

Orientation: Immersive media places us in an environment and astrophysical settings are by their nature abstract. Special attention must be paid toward orienting viewers in space and time. We owe it to our audience to ground them in a location that is familiar to proceed from and that we can refer back to in order to keep us oriented. Specific citation of epoch and time progression is also essential.

Depth Cueing: The surrounding universe is a vast three-dimensional arena, so depth perception techniques are necessary in order to impart understanding of the forms and relationships being presented. Motion parallax through angular camera motion is a primary means toward this.

Visual Coherence: Understanding what is in front of you through maximum use of contextual surroundings and continuity between surrounding elements.

3. Production Stages

The first stage in a production is the curatorial choice of topic. At any given time, several topic choices may be potent candidates. Potential topics

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are discussed by the curators of the Department of Astrophysics in consultation with the Director of the Hayden Planetarium and the Provost for Science at AMNH.

From the chosen topic the curators in consultation with the executive producer and director, both from the department of education, conceive a rough treatment for the production. From this, education goals are established and potential visual narrative arcs can be foreseen. From this process, proposals to funding agencies are crafted.

Concurrent with the proposal stage, institutional collaborators are recruited to partner on the production and help frame a broader perspective on the topic. International collaboration and perspective is especially sought in this process where the production will be marketed worldwide.

Once we have received funding and partnering, the core staff positions can be recruited, putting the producer and lead technical director in place to begin planning out the scope of the project and interfacing with engineering staff to establish a plan for anticipated resources. In this stage the treatment alternatives are examined in general to get a rough idea of what to expect for both internal and external computational needs.

Soon after the project is committed, a colloquium is held at AMNH to better resolve the science from curator-invited authorities and to share with them the goals of the show and demonstrate capability from previous shows. In the process of the colloquium, advisors are identified for the production that will assist the curators and specific research candidates to be visualized for the show are considered and discussed. This meeting has proven to be a crucial event where the scientists and creative staff come together to resolve a common vision of the show. This is also a time when all individuals responsible for the show get to meet each other and person-to-person bonds are initiated or reestablished around the central unifying priority of the show. Open discussion upon the proposed treatment culminates the process leading to a more consolidated vision and path forward to the stages beyond.

Following the colloquium, meetings are held with curatorial, writer, director and producers to begin the transformation of treatment into first version script. An outline serves to break down the notions of scenes in discussion and scriptwriter and director begin the process of first prose and storyboarding. The initial scene ideas are very much rough sketches to begin with. Curatorial and producer involvement is very close in this process with senior level management briefings also regular with concern for story, flow, and intelligibility.

First draft script is circulated to senior level for review and the initiation of a visual animatic with the storyboards begins the editorial process that will evolve the production all the way through to the finish. An independent agency administered review from selected museum visitors also provides feedback at this early stage of first draft and animatic. It is typical that alternate paths through the topic flow are considered and later discarded, just to be brought back again in a constant creative quest for story and logical arc. For our latest production, “Journey to the Stars”, about seventy script iterations were generated. For a twenty-four minute show, this production finally settled on an 1800 word script. Keeping word count down was a constant challenge; one version reached 3000 words!

As creative considerations are evaluated and refined, a highly technical workflow begins immediately after the colloquium. Data is gathered from science partners to be visualized by our production team. In many cases, having identified a potential contribution from ongoing research at the colloquium is just the start of either waiting for the latest results or actually helping to specify particular science that has yet to be conducted. In each space show production, very close collaboration with the scientists was required in order to best portray their science, and perhaps extend it beyond what they actually have available. In several cases, production budgets and / or priorities have helped generate new simulations and new results.

A range of data visualization tools and techniques are required for specific elements of any show. Special tools also need to be custom written by the technical directors, such as star renderers, geometric re-projection code and atmosphere shaders or contracted from specific collaborators such as with volume rendering. The volume renderer called MPIRE, which was originally developed at the San Diego Supercomputer Center had to be extensively modified to render the Orion Nebula in our first show, “Passport to the Universe”. Although its author, Dr. Jon Genetti moved to the University of Alaska, Fairbanks, we have used MPIRE in each space show with specific modifications contracted by him for specific show needs.

From samples of data visualization, scenes can begin to be assembled. In some cases, many different elements will compose a scene and they all need to be put together in proper relation to one another. Scene construction can be especially challenging with elements of different temporal and spatial scales. Direction must maintain how all scene elements must fit together and producers must make sure that fits the resources at hand within the schedule. Technical leads and digital artists may know little about the actual science, but their expertise in graphics and how to handle large production details carry the show. A production assigned astrophysicist has proven essential in the process and tends to communicate well with the technical directors. The technical directors must also maintain a close working relationship with the systems engineering staff to ensure the content being created can be managed, tracked and displayed.

As scenes are developed pre-visualization steps are taken with stand-in proxy objects especially for evaluating flight path authoring. A general “two-minute-rule” is applied to major scenes in the rough conceptual stage. Scene complexity and editorial will ultimately define how a scene evolves, but camera motion is of the utmost importance for orientation and depth cueing. Pre-visualization of camera around proxies typically takes a significant amount of production time, so as soon as scenes can be conceived and mocked up, the better.

The vast disparity of scales typically encountered in space show productions complicates camera continuity and hook-ups between independently authored camera segments. Experimental techniques to get around this are being currently researched by use of the multi-scale display software, Uniview that was developed to visualize the AMNH Digital Universe amalgam of 3D astronomical catalogs. Uniview was developed at AMNH as a graduate research project directed by the author with students from Linkoping University, Sweden. The company, SCISS AB grew out of the need to make Uniview a true product for the planetarium market.

As flight paths are resolved, rendering treatments are applied to the constituent elements of the scenes and composited together. As already mentioned, a range of rendering techniques are applied in any given scene. While this presents a management issue for resources, choices are mapped out as best can be foreseen from the beginning of the project as per total in house computational capacity and software considerations especially with commercial packages that may work out a discounting structure as per trade in promotional credit that can be garnered from association with the production. The rendering backbone we employ is a Linux cluster in excess of a hundred nodes.

Editorial process on the script and animatic proceed throughout the entire production with later stage executive and public reviews. Scenes are typically deleted at this mid to late stage as refinements either display problems or that there is simply too much in attempt to be told. As the visuals mature and the curatorial discussions of script adjust to the content, the production starts to sift itself into the late stages where the scene flow really needs to feel like a show.

Composer identification in the middle stages of production or sooner has proven at AMNH to be quite valuable. As visuals begin to cohere, these are shared with the composer in meetings with key production staff. Musical themes become part of the executive reviews so that composer can have feedback as they now join the production team, becoming an integral part of it.

Narrator choice is typically an executive decision, and one that gives character to process which to this point has been the domain of production staff scratch track recording of the script integrated into the animatic. It is worth noting that at AMNH, the name talent that is so closely associated with our shows has typically been a donation from the individual.

The final stage of the process is a multi-week in-theater sound mix. The Hayden Planetarium is a unique sound environment designed around an omni-directional seating plan. An array of twenty-four speakers is evenly distributed around the mid-level of the dome, while sub woofers are placed at the zenith and locations along the spring line. In addition, floor base-shakers and seat shakers compliment a theater that can be fully specialized for sound.

4. Production Team

The AMNH Production teams for the space show have tended to number about a dozen people total with not all individuals on the project for the full eighteen months anticipated for production. The list of principal production staff is as follows:

Curator(s)
Executive Producer
Director
Producer
Technical Director(s)
Assistant Producer
Astrophysicist
Editor
Camera Animator
Modeler
Image Processor
Compositor

In the case of our most recent production, “Journey to the Stars”, we had two curators, which was an unusual situation, and two technical directors, which was typical.

About the 4D2U Theater of the National Astronomical Observatory of Japan

Takaaki TAKEDA [*1],Eiichro KOKUBO[*2], Mitsuru HAYASHI[*3], Yumi IWASHITA[*4], Hidehiko AGATA[*5], Junichro MAKINO[*6], Syoken MIYAMA[*7], Tsunehiko KATO[*8], Toshiyuki TAKAHEI[*9], Hikaru OKUNO[*10], Sorahiko NUKATANI[*11], and Hitoshi MIURA[*12].

We have developed the four-dimensional digital universe theater, at which we can visualize the observational data and theoretical models, and numerical simulations. The astronomical objects cover all scales of universe, from the dust in the protoplanetary disks to the large scale structure of the universe. Recently we newly developed a stereoscopic dome theater, and we made several movie contents for the dome. Here we report the systems of the dome theater and our method of movie makings.

1. Introduction

The spatial and time scale of the universe is vastly large. The purpose of the 4-Dimaional Digital Universe (4D2U) project is to scientifically visualize such universe. We have visualized the universe in 4-dimensions (3-D in space and 1-D in time) by using stereo projection.

There are two purposes of 4D2U project. One is to provide general people with the latest results of astronomy in a scientifically correct and easily understandable way. The second one is to help astronomers intuitively understand their data by providing a 3-D view of their data. Now a days, 3-D view is necessary to understand the large-scale 3-D data.

In 2002 we have developed 3-D projection system with three flat screens, adopting circular polarization method for each screen [1]. In 2006, we have newly developed a stereoscopic dome theater. In this paper, we report the outline of the theater and the makings of simulation-visualization contents.

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2. Dome Theater Hardware

For the stereograph method for the dome, we adopted spectral method, and we use 13 projectors to cover the entire dome system. In projection with multiple projectors on the curved screen, several technological matters must be cleared, such as distortion of image or luminance correction in overlapped regions. As for the matters about projection in a dome theater, see literatures about these issues (e.g. [2],[3]).

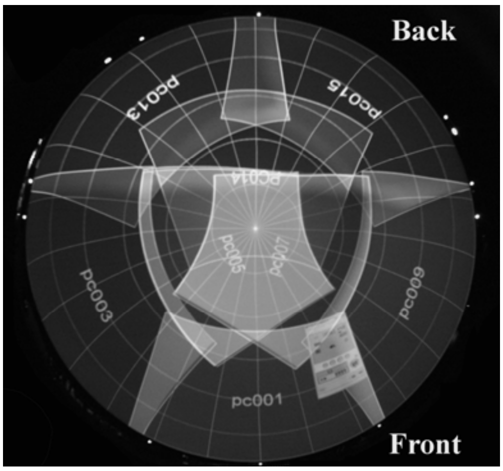

Fig.1. Projection in 4D2U dome.

Our 4D2U dome is not a symmetrical dome. The dome is tilted 10 degrees and all audience look at the front side of the dome. The entire screen is sliced to 8 regions, and stereoscopic images are projected to front 5 regions, and 3 regions in rear-side are monoscopic as shown in Fig. 1.

One of the reasons that the rear-side is left monoscopic is that the way how audience look back cannot be decided, as shown in Fig. 2. Since the positional relation between the left and right eyes depends on the way to look back, proper stereoscopic parallax cannot be determined in rear-side. However, if budget allows, fully stereoscopic dome is desirable in the point of view of the continuity of the image.

Fig.2. Difficulty to determine the parallax for rear side.

3. Dome Theater Software

The framework of software for dome theater is similar to previous 4D2U theater [1]. The theater is navigated by a software "Mitaka", a viewer of the model of the universe, using many astronomical catalogues or theoretical models. The theater demonstrator controls "Mitaka", and guides the audience through the universe, and show movies made from astronomical computer simulations here and there.

A. Mitaka

Mitaka can visualize all the scales of the universe seamlessly, from the Earth-Moon system to the large-scale structure. Mitaka is originally developed for the navigation system for the first 4D2U theater with flat-screens [1]. However, it can now handle real-time distortion of images and luminance correction, i.e. it can be used as a navigation system in multi-projection dome theater.

In 4D2U theater, Mitaka runs on each PCs connected to each projectors. One of these PCs is connected to the game-pad and serves as the controller PC. PCs for projection communicate with controller PC by TCP/IP protocol, and output coherent images according to the view point. We use one of projection PCs as the controller PC, since controlling is not so a heavy task.

An important point is that Mitaka is a freeware and one can use it freely. Building up a stereoscopic system with flat-screen with Mitaka is relatively easy, and several groups for education or public outreach build up such systems.

A. Simulation Movie Library

The movie library is the collection of animations made from the results of computer simulations. Though making a movie for dome projection is time-consuming task, we have developed several movies for dome projection by now (Formation of the Moon, Formation of Terrestrial Planets, Dynamics of the Ring of Saturn, Formation of a Spiral Galaxy, cD Galaxy, and the Large Scale Structure).

In the field of astronomy, dynamics of many particles is important. For example, a galaxy consists of many stars, or the Saturnian Rings consist of many small icy moonlets. To effectively visualize many body simulations, we developed an original application [4] using OpenGL libraries. Since the graphic acceleration using a graphic boards with projective transformation cannot deal with fish-eye rendering directly, we adopt cube-map rendering, i.e. we render five movies for each side (front, left, right, top and back), and combined them for dome projection.

As for visualizations of fluid simulations or making of 3D-model based animations, we use commonly-used 3D software or visualization software such as Maya, Lightwave 3D, AVS and Pov-Ray. We render fish-eye images directly if the renderer can, or cube maps if it cannot.

4. Stereoscopic Configure

In a virtual reality system, the stereoscopic parallax of the projection image reflects the direction of the eyes of the user. However, in a stereoscopic theater, the show cannot trace the move of the eyes of each person, and stereoscopic parallax must be fixed one. In a dome theater, ideally speaking, the parallax should be direction-dependent, i.e. camera positions for images projected on non-front side should be off-set along a line between left and right eyes looking at that direction (Fig. 3).

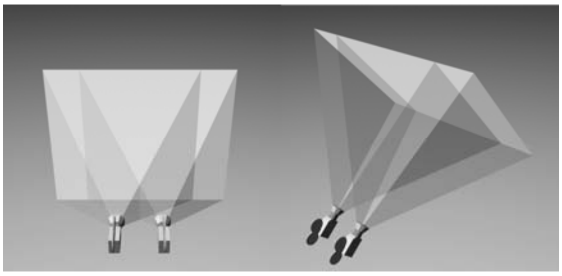

Fig.3. Ideal Parallax setting for different directions

However, this means that the camera positions should move seamlessly corresponding to the direction of sight, and such a rendering is tricky even in a ray-trace based rendering, and much more difficult in rendering accelerated by a graphic board using projective transformation.

For now, we adopt the simplest way for stereoscopic projection in the 4D2U theater, i.e. we used fixed cameras for left and right eyes, respectively. Camera offsets are set suitable for persons looking straight forward. Thus, the stereogram parallax in the non-front side becomes incorrect, and we must keep the main object to be in the front-side of the audience, imposing some limitations to camera works. We found that as the main objects are set in front side, audience do not care much about the incorrect parallax in other sides.

There are two major methods in stereoscopic fixed camera settings, the off-axis and the toe-in methods. In off-axis method, the parallax purely comes from the difference of position of cameras. In toe-in method, the parallax of distant objects comes from the convergence of the cameras (Fig. 4).

Fig.4. Parallax for the right side in toe-in method

The toe-in method in a dome has a merit that the distant objects, i.e. starry background in astronomical contents, can be set beyond the screen, and the parallax of distant objects in left- and right- sides are relatively correct than that of off-axis method. (Note that the parallax in the top-side becomes worse than that of off-axis method due to the convergence.) In 4D2U theater, we adopted the toe-in method, evaluating the merit exceeds the demerit. However, the merit that the objects can be set beyond the screen may diminish in a dome large enough, and the off-axis method may be better in such a dome.

5. Summary

We have developed the 4D2U theater system based on the latest astronomical data. We have developed a spectral stereoscopic dome and established the basic methods for 3-D visualization in the dome.

Currently, we have shows twice in a month to the public and met a good public response, and we also provided our contents to museums and planetariums etc. Some of the data are also available on the project web page:

http://4d2u.nao.ac.jp/

ACKNOWLEDGEMENTS

The 4D2U dome development was based on “Construction of an Image Distribution System for the Four-Dimensional Digital Universe” funded by the Special Coordination Fund for Promoting Science and Technology of the Japanese Ministry of Education, Culture, Sports, Science and Technology as part of their Program for the Effective Promotion of Joint Research with Industry, Academia and Government.

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Synra Dome, the first public stereoscopic dome theater in Japan

Toshiyuki Takahei*1

In the summer of 2008, the first Japanese public stereoscopic dome theater 'Synra Dome' was opened. Based on 4D2U and other new technologies, it represents cutting edge science visualizations and various usages of such real-time immersive environments. These days we play stereoscopic dome content about astronomy and life science as weekday programs, and a scientific live show by scientists called 'Universe' on the weekend. We're also holding public technical workshops as a free space to discuss the possibility of immersive visualization and to seek new collaborations. New and cutting edge projects have begun in this Synra Dome, and we continue to foster this environment.

1. Background

Since we developed the first stereoscopic theater '4D2U Dome' in the National Astronomical Observatory of Japan, we wanted to spread this successful result to the public. For that purpose we had to build another one which opens everyday for the public. We decided to develop this first public stereoscopic dome theater at the Science Museum, Tokyo. In building this new dome, we extended its purpose for visualizing not only astronomy but everything else, and make it a place to seek possibilities of this new media. We named it the 'Synra Dome', where 'Synra (Shinra)' means 'everything in the universe' in Japanese. I'll describe here detail about this new stereoscopic dome theater [1].

2. Dome System

Synra Dome is 10 meters in diameter, with an 18 degree tilted dome screen. To avoid visual degradation by stereoscopic viewing, we use totally seamless screen 'Skylight-Screen' manufactured by Tenmado-kobo Company. We choose Infitec stereoscopic technology same as 4D2U dome, and we use twelve BARCO Sim5R projectors for stereoscopic projection. Each projector is connected to its own image generation PC, and there is one more PC for operation, so there are thirteen PCs total for Synra Dome. Furthermore a special purpose super computer MDGRAPE-2 cluster is directly connected to these PCs to accelerate some kinds of real-time simulations.

Fig.1. The first public stereoscopic dome theater in Japan.

At Synra Dome we developed various original software and integrated them to realize a unique and flexible theater system. Mitaka Pro is an improved version of space viewer Mitaka which was originally developed by NAOJ 4D2U project. We use Mitaka Pro for weekend live shows to visualize astronomical topics interactively. Quadratura is a brand new real-time presentation tool designed for immersive environments such as dome theaters. It is totally integrated in Mitaka Pro for intuitive dome presentations and embedding special modules such as real-time galaxy collision simulation. Well-known space visualization software Uniview is also installed for the first time in Japan, and working in full-dome stereoscopic mode makes it the first in the world. There are also many original tools such as full-dome movie player, dome master slicer, theater control system etc.

3. Weekday programs

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Currently we have 3 original stereoscopic full dome movies on weekdays and on Sundays.

The first one is ‘Cosmic Discoveries’. (see [2]). The world’s best real-time space image generation software “Uniview” was used to create Cosmic Discoveries, the latest images of the cosmos. It is an original work, significant as a new generation of dome content created using real-time visualization technology.

Fig.2. Cosmic Discoveries, ©Orihalcon Technologies, Inc.

The second one is ‘The Central Dogma’. (see [3]). It is an original work by RIKEN Omics Science Center based on the latest research findings. It introduces life’ s most fundamental mechanism, the “Central Dogma” of assembling protein based on the design information written in genomes (DNA).

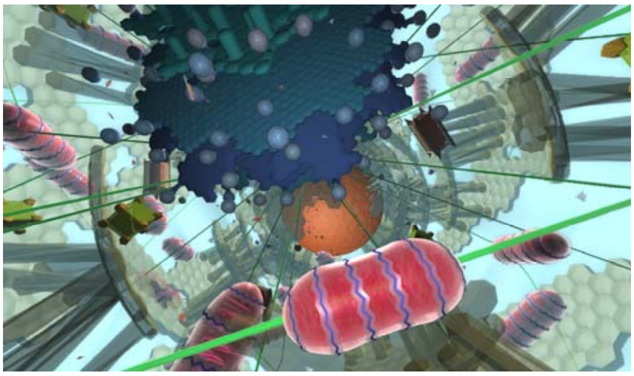

Fig.3. The Central Dogma, ©RIKEN OSC

The third one is a simulation based 4D2U Project which was made using large-scale simulation visualization technology developed by the project. This is the first stereoscopic full-dome screening of ‘the formation of the moon’, ‘the formation of a spiral galaxy’, ‘large-scale space structures’, etc. outside the NAOJ’s facilities. (see [4]).

We keep developing new full-dome shows about many fields in science. The next one will be a journey into deep sea.

Fig.4. Formation of a spiral Galaxy, ©NAOJ 4D2U Project

4. Weekend Live Show

We also have a Scientific Live Show called ‘Universe’ playing every Saturday. (see [5]). It is a live science show that presents the latest science topics including astronomy, using real-time computer simulations and networks. The show is hosted by “Facilitators” who are front-line researchers. They are assisted in operating the computers and a variety of other tasks by “Assistants” from the student volunteer group “Chimonzu”. The first live show was held in the hall “Universe” of the fourth-floor of the Science Museum (in Chiyoda Ward, Tokyo) on April 21, 1996, and since then has continued as a regular show performed twice every Saturday afternoon. From August 2008, it has been updated to become a live stereoscopic full-dome show performed in the ‘Synra Dome’. Its unique concept is direct communication between scientists and guests, so we use Mitaka Pro for interactive visualization, and the super computer accelerated galaxy collision real-time simulation to feel a taste of real science.

Fig.5. Scientific Live Show ‘Universe’

5. Various Events

After building the Synra Dome, we hold regular Synra Dome Tech Demo events at which all of the contents and software Synra Dome has are demonstrated and where the demonstrators and participants talk about the possibilities of media, such as Synra Dome and stereoscopic domes. The aim is to explore new initiatives and collaborations with as many scientists and creators.

For the Japanese Planetarium Community we hold a workshop to introduce cutting-edge technologies and scientific visualizations to enlighten them to use the dome for broader purposes and targets.

We also hold some art/music events in the dome environment. The first one is stereoscopic Visual Jockey live "Overlapping Spiral"; a collaboration of young progressive sound artist Saitone and image creator VJ REEL. (see [6]).

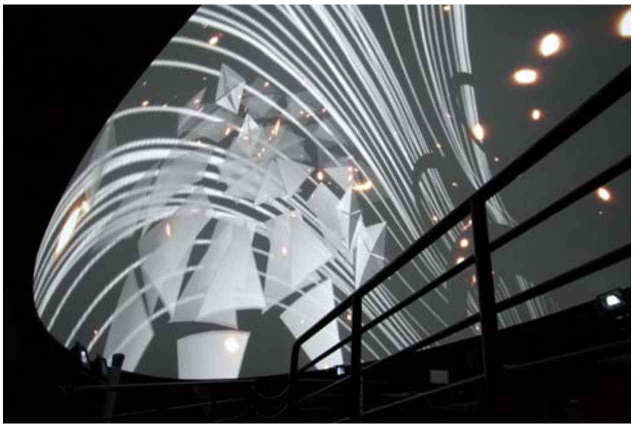

Fig.6. Visual Jockey Live 'Overlapping Spiral'

Another one is 'BELLA GAIA' private preview, to introduce the collaboration of Kenji Williams and Uniview to audiences and sponsors. (see [7]).

Fig.7. Kenji Williams Live 'BELLA GAIA'

For the Live Show, we sometimes have special programs such as Nobel Prize special presentations, and Total Eclipse live relay events etc.

6. Future Plans

At last we have a new space to create a new future. These days we frequently invite talented people from various fields of science, art, entertainment etc, to seek new collaborations in this dome theater. Real-time systems and its interactive visualizations in such a super immersive environment seem very promising. Please keep your eyes open for the next new thing happening here, and please join us!

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3D Stereoscopic Visualization at Imiloa Astronomy Center
New Datasets from the Maunakea Observatories

Shawn Laatsch*1

Imiloa Astronomy Center opened the world's first full dome 3D stereoscopic planetarium. This was installed in December of 2007 and opened in January 2008 to the public. Our facility has partnered with the observatories on Maunakea to bring new datasets into the planetarium. These have been used by astronomers to present their finding to the general public and are starting to be used by astronomers for research into science visualization. In the paper I will discuss some of the datasets and the methodology used to bring CFHT, Joint Astronomy Centre, and other data into the planetarium. This data is in multiple wavelengths of the spectrum. Imiloa also has produced a 3D Stereoscopic planetarium production called Awesome Light – An Update from Maunakea observatories. This program features 3D full dome time lapse footage of Subaru Observatory, CFHT observatory, and Gemini Observatory. I'll give a brief description of the program and methodology for creating the stereo footage for use in digital full domes.

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1. Introduction

Imiloa Astronomy Center is located in Hilo, Hawaii between the University of Hawaii at Hilo and the base stations for several of the Maunakea observatories. Maunakea is home to 12 observatories operated by a number of countries around the globe. Imiloa was created to inspire the next generation of explorers by sharing the astronomical science conducted on Maunakea through a Hawaiian world view. Its proximity to these astronomical observatories has given it unique access to astronomical data sets and astronomical discoveries. The facility is comprised of a planetarium, exhibit hall space, classroom, and a cafe. The planetarium is a 16 meter, non-titled dome housing 120

unidirectional seats. It has a Sky Skan definiti stereoscopic projection system, tri-colored LED coves, and a 5.1 digital audio system. The exhibit hall houses a number of components exploring Maunakea astronomy and Hawaiian Culture. Two of the most popular exhibits are the 4D2U theater which was a gift from NAOJ/Subaru Telescope to Imiloa, and the Science on a Sphere a gift from NOAA. This is a three screen stereoscopic theater that can seat up to 20 people. It uses rear screen polarized projection to display astronomical content through the Mitaka software packaged developed at NAOJ. Science on a Sphere is a two meter sphere that uses 4 projectors to show spherical images of ocean and atmospheric data, NASA planetary data, and playback content designed for spherical projection. Both of these exhibits are capable of displaying real time and playback types of content.

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2. Installation of the planetarium 3D system

Crates containing computers and their racks, cabling, steel projection stands, and SXRD projectors started arriving on November 13th, 2007 filling Imiloa's loading bay. Sky Skan staff arrived the following day to begin the installation of the system. Install was to be no easy feat, as we had a temporary system running in our dome, and the holiday rush of public visitors meant we could not close down the planetarium. Installing after hours and overnight was required, and so began about a month of very long days...some which lasted 16-18 hours plus for the planetarium staff. Additionally, Imiloa's planetarium theater was not designed for SXRD projectors when it was built. Cove modifications and other construction would be needed. Ingenuity was required to get these projectors in place and get them properly vented into our HVAC system. The first steps were installing the computer racks holding 18 PCs. The system has 16 channels of video (4 per SXRD projector), along with a master computer and an audio computer. Each computer has half a terabyte of memory and the graphics cards have 1 gig of ram. Placing the SXRD projectors into place was step two. Steel stands roughly half a meter square by 2 meters in height were to be bolted into the concrete floors in four locations where the projectors were to be placed. At the top of these stands, an adjustable angle platform was attached to lock into the projectors and hold them in place at the correct angle and height. Once the stands were in their permanent locations the Sony SXRD's weighing in at 100 kg (225 lbs) each were hoisted into position. Fiber optic and CAT5 cables were then strung from projectors to the racks along the cove shelves. Each projector is connected to four IG computers, and a CAT5 line provides communication from Digital Sky and SPICE to the projectors. Lenses for the SXRD's were placed into the projectors, and on November 21st, 2007 the first light from the system was on the dome. Forty thousand lumens on a 16 meter dome is an incredible sight! The first views, even before alignment and calibrations were breathtaking. Following first light, alignment and calibration of the system was first completed in 2D and then in 3D stereoscopic mode. This detailed and delicate work took a number of evenings. Sky Skan software combined with the Sony controller allowed for geometric transformations and color corrections. Binoculars were used a number of times to make sure alignments were razor sharp. During this time the Sony SXRD projectors were connected to Imiloa's HVAC return ducting. Venting the projectors into HVAC accomplishes two objectives; first it reduces heat in the cove areas, and secondly it greatly reduces fan noise from the projectors yielding a quieter theater. On December 17th of 2007 installation of the system was complete. On January 13 and 14 a special opening event was held for observatory directors, astronomers, and planetarium dignitaries. The facility opened to the public on January 15th, 2008.

3. Astronomical Datasets – First Steps

While installation was taking place, discussions were taking place with a number of observatories on possible data for display in the dome. The goal was to open the facility with two or 3 examples of datasets from the observatories. The planetarium contacted the observatories and the ones below provided the first new data for the system.

Dr. Jean Charles Cuillandre and Dr. Stephane Arnouts of the Canada France Hawaii Telescope (CFHT) were the first astronomers to propose a dataset. For five years the CFHT telescope had conducted a large campaign of observation to discover exploding stars in the distant universe. Using a new generation of large CCD camera (MegaCam) four locations in the sky were regularly allowing astronomers to discover several hundred of supernovae. When stacking together the observations reveals a large amount of faint galaxies spread all over the four fields. When compared to the well know Hubble Deep Field observed by the Hubble Space Telescope, each CFHT deep field (a one degree square field) covers an area 400 times larger than HDF, making them of particular interest to study the formation and evolution of galaxies. Photometric redshifts of these galaxies allowed determination of distances of these island universes. Using this CFHT was able to build a three dimensional map of the galaxies in the universe. Data from the four fields allows travel across the last 8.5 billion years of the universe (or equivalent up to redshift z=1.2). This is roughly 2/3 the age of the universe (13.5 billion years). Four of these fields were observed with a half a million galaxies visible in the survey. CFHT worked to give the data for these four fields to Imiloa and Sky Skan in a Partiview format, the same format used by Digital Universe to display positional astronomical data. This was then adjusted and tweaked for display in Digital Sky for display in our planetarium. After a few tests the set was ready for display for audiences in our dome.

Dr. Antonio Chrysostomou, Associate Director of the James Clerk Maxwell Telescope (JCMT) proposed showing a 3D volumetric view of gas flows in the Whirlpool Galaxy. Data collected by the HARP instrument on JCMT shows M51 warped by interactions with its companion and gas flow motion within this famous spiral. HARP data required special formatting as the data is showing the motion of gas as its third dimension instead of distance which is the usual “z” point for data. HARP provides a volumetric cube of data and those points were then converted into sprites in Partiview. Colors were added to show gas flow moving toward (blue-shifted) and away (red-shifted). The result is a dramatic view of the Whirlpool showing the interaction between the main galaxy and its companion. This submillimeter view provides a new way of seeing a galaxy volumetrically.

Dr. Andy Adamson, Associate Director of United Kingdom Infrared Telescope provided data from the UKIRT Deep Infrared Sky Survey Ultra-Deep Survey (UDS). This data covers an area of almost one square degree on the sky and uses UKIRT's wide-field imager (WFCAM). About 100,000 galaxies have so far been discovered in this field, and many more are promised as the survey depth increases. The largest redshift represented in the survey is just below 6; with the Universe currently about 13.5 Gyr old, these galaxies represent the Universe when it was very young - less than 1Gyr, or only about 7% of its current age. By comparison, most galaxies in the observable Universe were assembled at redshifts of about 2, more than 2 billion years later than these objects. When comparing this data to the Sloan and 2dF surveys, the UDS extends much further back in time. Once again Partiview formatting was used to bring this positional data for the galaxies into our system.

Dr. Adamson also provided twenty 4096 x 4096 image tiles from UKIRT’s galactic plane survey or GPS. These were down sampled from original images that are 16K x 16K in size. These stunning images show the plane of the Milky Way in greater detail than visible light can provide. The GPS covers the galactic plane to latitudes up to 5 degrees from the mid-plane, and longitudes from the Galactic Center in Sagittarius to the south to Cassiopeia in the north. At present the GPS has detected more than 1 billion objects, the great majority of them stars; the survey is being studied for new star clusters, new globular clusters, star formation regions and galaxies hidden behind the mid-plane extinction. While these are currently static images, Imiloa is working with Sky Skan to create a method for tiling these image allowing zooming in and exploring the images in greater detail.

This was the first times that astronomers were using a planetarium to present their data in 3D stereo in a planetarium environment. These first steps launched Imiloa on a path to bring this information to the public and we are currently discussing with the observatories mentioned ways of releasing this data for other planetariums to use and display in their domes. One way this data is currently being utilized at Imiloa Astronomy Center is our regular presentations called “3D Hitchhikers Guide to the Universe.” This hour long tour from Earth out to the edge of the Universe as we know it incorporates these datasets. Monthly we do a program called Maunakea Skies in which we do an in-depth sky tour, followed by a presentation by one of the observatory astronomers. This program now includes flying out to some of their discoveries in 3D stereo. Attendances for this show have increased and we find that many astronomers really enjoy having an opportunity to use the 3D system to present their findings to the public.

4. Awesome Light–Using real imagery in the dome

Our first stereoscopic digital dome production is called Awesome Light: Mirrors on the Mountain. The initial idea was to create 5-10 minute science updates exploring the latest astronomical discoveries using real footage from the observatories, making the audiences feel as if they themselves were with astronomers at the telescopes. As the project progressed, it was clear that in order to do justice to the observatories, and place them in the context of their location atop Maunakea, a sacred mountain to Hawaiians, that a full length program was the way to go.

The first step in our process was to choose the observatories for the program knowing we could not cover all of them in a 20-25 minute program. For the first one we decided to go with an optical theme and chose the Canada-France-Hawaii Telescope (CFHT), Gemini North, Keck, and Subaru observatories. Once they were selected, Imiloa staff met with the observatories to discuss latest science results and look for the best candidates to share in a public planetarium show. The results needed to be dramatic, but also explainable in five minutes or less while giving a general overview of the observatory itself and its technology. Once possible science topics were determined we dived into the task of how to link these observatories and tell the story in a logical progression and began work on scripting. For the visual look and feel of the show, we wanted to do something dramatically different than other full dome shows by showing as much real footage as possible and keeping computer graphics limited to showing astronomical datasets or processes one could not observe directly.

After a variety of tests and experimentation, it was determined that time lapse photography using digital SLR cameras was the way to go. While this seems like an easy solution, one must keep two cameras firing in synch to provide left and right eye views for the stereo 3d effect. The spacing of the camera lenses is critical as it should be as close to the interocular distance as possible. Lenses need to parallel, perfectly aligned, and critically focused.

Complicating things further, all of this needed to be done at altitude (14,000 ft at the summit of Maunakea) where the air is thin and cameras and computers sometimes behave a bit differently as they cannot cool themselves as rapidly as is possible at sea level.

Filming for Awesome light started in June of 2008. Steve Savage and Jack White from Sky Skan, Kirk Pu'uohau-Pummill from Gemini Observatory, and I loaded up two four wheel drive vehicles in Hilo with cameras, tripods, heavy clothing, batteries, flash cards, and bottled water. From Hilo we headed up to Maunakea to set up at the construction camp, which is just below Hale Pohaku (Astronomer's Village). The construction camp would be our home for the next 12 days as we made numerous trips to the summit filming CFHT, Gemini, Keck, and Subaru. Working in a cold desert altitude is grueling. The lack of oxygen means everything takes more effort, and one has to pay careful attention not to make mistakes. It is also important to stay hydrated as Maunakea is a desert and the water seeps out of you very fast. Drinking water is essential both in keeping hydrating, but it also adds oxygen into your system which helps you feel better and keep focused.

Our first day of filming we started by filming a sunrise shot of Maunakea, watching the marine layer encroach. This shot would be for the opening and to set the context for the show. Maunakea is the tallest mountain on Hawaii and is a dormant shield volcano. From Saddle Road, you can see that it is massive. After a quick breakfast at Hale Pahaku (HP) we ascended and set up inside CFHT. This 4 meter class instrument is 30 years old and is striking with its huge equatorial mount. (Gemini, Keck, and Subaru are newer scopes and all use alt-azimuth mounts.) CFHT is a great example of how older telescopes who update their instrumentation can make dramatic discoveries, and stay viable in the age of larger mirrors. The staff of CFHT was extremely helpful and moved the dome and telescope as slow as possible to help us maximize the effectiveness of time lapse filming. After finishing interiors, we headed down to HP to unload cards and get dinner before heading back up for sunset shots of CFHT and Gemini.

Several more days of this schedule ensued. While filming in Gemini we were privileged to be on the catwalk when the vent gates opened at sunset. It was a spectacular view and one I'll not soon forget. At Subaru we filmed an incredible instrument change using a specially designed turntable. The incredible access was really wonderful. It was incredible to have such access and see the "personality" of each observatory come through.

We did come down the mountain to test stills in the dome, checking frames and clips along the way. A great deal of grading and post processing would be needed, but the shots were incredible and nothing like this had been done on the dome before. Several months of post production, data set programming, and other tweaks were needed.

In late 2008 we opened a beta version of the show at Imiloa. Audiences were wowed by the 3D and many commented that the show made them feel as if they were inside these observatories and that they could reach out and touch these incredible instruments of discovery. In Spring of 2009 we went back and re-filmed some of the scenes improving the shots significantly. We added dolly shots to our routine, creating dynamic motion in scenes. We also added Keck to the mix, as originally CFHT, Gemini, and Subaru were planned for the smaller updates. Keck fit the mix well as it completed the large optical instruments, and increased the length of the show from 17 minutes to 23 minutes making it a standard full dome feature show.

There is more to come as we started filming a second Awesome Light show in late May of 2009. This second show features radio and sub-millimeter astronomy of Caltech Submillimeter Observatory (CSO), James Clerk Maxwell Telescope (JCMT), Smithsonian Submillimeter Array (SMA), and the Very Long Baseline Array (VLBA). This show will be complete in eary 2010, and we expect to finish up the observatories with a third Awesome Light show with filming in 2010 and a release date of early 2011.

5. Conclusions

Stereoscopic technology has the ability to change the role of a planetarium dramatically. It allows us to teach and entertain in new ways, showing spatial relationships in a dynamic way. A key to really utilizing the technology is having a live knowledgeable presenter, as this creates an experience that goes far beyond what an IMAX or movie theater can provide, let alone the standard, Earth-based planetarium view. Imiloa is now viewed as a new resource for astronomers and our local university scientists in a number of fields have discussed showing non-astronomical content in the dome for their classes. Both groups see great potential in this new technology for presenting science. Astronomers and observatory staff have commented that this new technology “now makes the planetarium useful to astronomers...compared to when all planetariums could do was show the constellations.” This system will now aid their research by bringing their data to life and we look forward to sharing their new research with the public and the planetarium community.

Immersive Scientific Visualization in Education, Storytelling and Art

Ed Lantz*

Scientific visualization is regarded as a tool for scientists to represent, investigate and understand complex data. Much of the knowable universe can now only be experienced and understood through scientific visualization, making this an essential modality for sharing our expanding view of the physical universe with non-scientists. Through education, storytelling and deeply engaging art, nonscientists assist in the assimilation of scientific knowledge into deeper personal and cultural meanings - fueling an expanded cosmology or "world view" - in ways that scientists cannot. Group immersive visualization environments, particularly "fulldome" or digital dome theaters, are powerful venues for the dissemination and assimilation of new scientific understandings into personal and cultural cosmologies. Recent trends in digital planetarium programming are discussed along with the need for scientific visualization in digital domes.

1. Introduction

In 1987 McCormick defined scientific visualization as "the use of computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results [1]." The implication is that scientific visualization is an aid for *scientists* in understanding simulations of physical phenomena. Indeed, computer visualization techniques have been extremely successful in advancing numerous fields of science, ranging from physics to chemistry, biology, materials science, earth science, cosmology and astrophysics. Practical applications of data and information visualization include engineering, medicine, nanotechnology, gas and oil exploration and pharmaceuticals.

It might be argued that much of the universe can only be known through the tools of scientific visualization. From the large-scale structure of the universe, to galaxy collisions, fluid flow, down to atomic models and quantum phenomena, scientific visualization provides scientists with windows into phenomena that are either too large, too small, too fast or too slow to directly observe. While scientists are rightfully tasked with opening these windows into the knowable universe, such windows should not be reserved for scientists alone. It might even be argued that the highest role of science is revealing the mysteries of the universe and rendering them understandable and accessible to all humanity.

Recent advancements in digital planetariums (often referred to as “fulldome” theaters or “digital domes”) now allow the rapid and affordable dissemination of scientific visualizations in a powerful immersive format [2]. Artfully combined with narrative, music and surround audio, the format provides a compelling medium for the public assimilation of scientific knowledge and visuals into deeper personal and cultural meanings and realizations. The medium fosters an expanded cosmology or “world view” for individuals based on scientifically inspired simulations of phenomena that lie beyond our everyday experience.

2. Digital Domes

Digital planetariums are essentially group immersive visualization environments capable of navigating audiences through real-time and pre-rendered scientific and information visualizations in addition to other programming. The planetariums of the world are rapidly converting into digital domes. There are currently 519 fulldome theaters listed in Loch Ness Production’s *Fulldome Theater Compendium ONLINE!* [3]. In 2008 alone over 170 additional digital domes opened, ranging from large public facilities in major metropolitan areas, to small school planetariums, to even smaller portable domes. Many were optomechanical planetariums that added digital projection capabilities or completely converted to digital. There are over 3,300 planetariums worldwide serving 110 million visitors annually – approximately 16% of these domes are now digital. The trend towards digital is expected to continue and possibly accelerate in the coming years.

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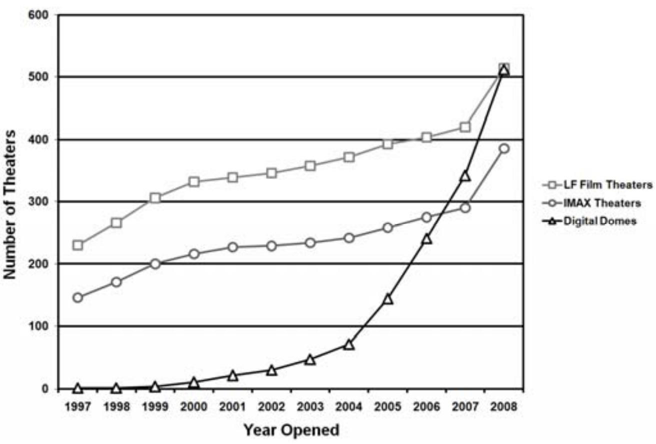

Table 1. Worldwide growth of digital domes. (courtesy Visual Bandwidth, Inc.)

Most digital planetariums systems sold today are capable of navigating, in real-time, extensive 3D models and simulations of the known universe including simulated spaceborne views of the Earth using data from MODIS sensors on NASA's TERRA and AQUA satellites, satellite and space debris tracking, simulations of planets and their moons, nearby stars from the Hipparcos and Tycho-2 3D star catalogs, the Tully and 2μm All-Sky Survey galaxy datasets, multi-wavelength skies, deep-space quasars and the microwave background radiation all-sky image captured by the Wilkinson Microwave Anisotropy Probe (WMAP). These datasets and simulations can be navigated in real-time with the help of a live presenter, or rendered into a show. The most popular collection of datasets for digital domes is the Digital Universe Atlas from the American Museum of Natural History's Hayden Planetarium. This curated package of "data products" is distributed by major fulldome vendors who offer the capability to navigate the datasets in real-time on their server clusters with their own value-added features.

Digital planetariums have naturally placed emphasis on astronomy because planetariums historically emerged as domed simulations of the celestial sphere. However, naked-eye astronomy is only a narrow branch of astronomy and astrophysics, which is only one branch of physics, which itself is only one of the sciences. In these difficult economic times, many digital planetariums find success by expanding their programming into other sciences and even into arts and humanities. Interestingly, scientific visualization has much to offer in all these areas. Digital domes provide a compelling opportunity for the scientific visualization profession to grow while fulfilling important cultural needs.

3. Education

Efforts have been underway over the past decade to increase the role of scientific visualization in the classroom [4]. Scientific visualization tools used by scientists are often inappropriate for students because of their reliance on specialized knowledge of expert users, and the need for high-end technology infrastructure and specialized training of instructors in schools. Digital planetariums allow concentration of classroom-based scientific visualization efforts into a single, powerful group visualization theater.

Besides applications in scientific discovery, engineering and technology, the most widespread application of scientific visualization is informal science education, including science documentaries, television programs, IMAX films and digital planetarium programs. One of the leading scientific visualization teams in the U.S. is the National Center for Supercomputing Application's Electronic Visualization Lab led by Donna Cox. Located on the campus of the University of Illinois at Urbana-Champaign, Cox's team has provided visualizations for IMAX films, digital planetariums, HD documentaries and more [5]. Topics include atmospheric imaging, cosmology, oceanography and astrophysics. These programs weave visualizations into journeys or storytelling themes.

4. Storytelling

The presentation of scientific visualizations in a theater setting presents some unique challenges, especially when simulating a journey where storytelling is the focus rather than the data themselves. Scientific visualizations become scientifically accurate props, settings, or special effects. Absolute accuracy may take second place to "look" and "feel."

In some cases, "best guess" spatial or temporal extrapolations of datasets are required. Examples include creation of a complete navigable model of our own galaxy (which cannot be fully imaged from our position in the spiral arm), or recreation of nebulae with large error bars on star positions (forcing assumptions about star positions).

In other applications astrophysical simulations are possible, as with solar system formation, black hole visualization, galactic collisions or early evolution of the universe. In cases where insufficient data exists and simulations are unavailable, artistic license must be employed based on the best data available in the tradition of astronomical art [6]. Examples include a simulated sub-surface expedition to Europa or journey to an extrasolar planet.

5. Art and Culture

Because planetariums are science-focused institutions, it is natural that a blend of art and science would emerge as a popular means of cultural entertainment under the dome. So-called “ArtScience” or “SciArt” productions are steadily gaining in popularity in the U.S.

Art and music are powerful modalities for stimulating unique neural states associated with affective educational and cultural entertainment goals. Music is especially well known to be a powerful mood-altering agent [7]. Beautiful nature scenes have been shown to lower blood pressure and reduce stress [8]. Immersive SciArt presentations are especially powerful, drawing upon the awe-inspiring natural beauty of the universe as depicted in scientific visualizations. It is difficult to ignore the parallels of immersive ScArt to opera’s formation in the Reniassance by the Florentine humanists who gathered as the "Camerata de' Bardi" and sought to uplift humanity through beautiful, enriching art.

One example of a SciArt production is *Bella Gaia*, a touring planetarium performance and collaboration between Carter Emmart, director of astrovisualization, and creator Kenji Williams [9]. The production seeks to trigger the “overview effect” in planetarium visitors, an experience reported by some astronauts who experience lasting affective shifts from seeing the earth from orbit [10]. It is hoped that the exposure to this experience will expand nonscientist’s view of the earth as an interconnected biosphere and invoke “conservation consciousness” without a lecture on the importance of recycling or environmental responsibility.

Fig. 1. Kenji Williams performs *Bella Gaia* (photo courtesy Remedy Arts)

In the Bella Gaia performance, classically trained violinist Kenji Williams performs live over looping electronic beats while audiences gaze at the earth from space produced by SCISS’ Uniview using JPL’s OnEarth and NEO datasets. Occasional excursions to the earth provide a multicultural dimension to the piece. NASA Astronaut Piers Sellers, upon seeing the production, said "BELLA GAIA is Just Beautiful. It really felt like I was back in space." Bing Quock, Assistant Director of the Morrison Planetarium at the California Academy of Sciences, said "I believe Bella Gaia can be a truly transformative experience that inspires people to think of our world as not a collection of countries and regions but as ONE place, and to be more aware of the alarming fragility of our planet."

Another SciArt collaboration is First Friday Fractals, presented by Jonathan Singer of the Fractal Foundation at the New Mexico Museum of Natural History and Science in Albuquerque, NM. This extremely popular program combines a presentation on fractal science, and a visual journey through infinitely complex fractals set to music [11].

6. Personal cosmology

Cosmology is the study of the universe in its totality, including humankind’s place in the universe. Cosmology originated in ancient civilizations including the Egyptian (c. 3150-31 BC), Babylonian (c. 2300-500 BC), Mayan (c. 2000 BC to 250 AD), and Greek (c. 2000-146 BC) civilizations. Religions have historically been the keepers of cosmology, using art, literature, and storytelling to communicate their world view. Architecture has also played a prominent role, with awe-inspiring cathedrals, temples and mosques immersing their subjects in rich religious symbology and metaphor. These various modalities (art and music, literature, architecture and storytelling) facilitated the assimilation of religious "knowledge" into deeper personal and cultural meanings, forging a religious cosmology that remains deeply infused in our world cultures even today.

Science has now taken its place as the institution responsible for defining at least the physical origins and evolution of the universe – a physical cosmology. Yet, despite the best wishes of many science educators, the personal cosmologies of non-scientists continue to be steeped in metaphysics, a multitude of world religions, and esotericism which often compete with the views commonly held by mainstream scientists. For a given individual, these world views intertwine into a "personal cosmology" or overall world view.

As science expands the known universe, new cosmologies are born, sometimes revising metaphysical, religious or esoteric notions – at least for the scientists who are exposed to these discoveries. Some have called for a new cosmology that weaves the many revelations of science into an integrated whole [12-14]. In this sense, digital planetariums are not unlike the cathedrals and temples of the past, using art, music, storytelling and powerful visualizations to immerse visitors in a scientific world view. Assisting the assimilation of scientific knowledge into deeper personal and cultural cosmologies is a task that lies beyond the purview of scientists and, at times, even beyond educators. At the extreme, it lies in the realm of poets, artists, and storytellers who can bring new realizations to life, providing them with context, emotional meaning and deeper personal value.

7. Conclusion

If we are to realize the full value of scientific visualizations, we must not limit their access to scientists, engineers and educators alone. Storytellers and artists play a vital role in the dissemination and assimilation of new scientific understandings into personal and cultural cosmologies. Digital planetariums combine these modalities in a powerful group immersive setting, and represent a growing demand for scientific datasets, simulations and visualizations.

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Scientific Visualization Adoption in Domes and Digital Planetariums

Staffan Klashed*

This paper takes a birds-eye perspective on live scientific visualization (”sciviz”) presentations and discusses the adoption rate of technology to enable such programming in digital domes and planetariums. It is concluded that smaller domes have a higher adoption rate than larger domes, and that the adoption rate while often perceived as marginal is actually already fairly high.

Measures to increase the adoption rate even higher, especially in larger domes, are discussed. We conclude that audiences react well to live sciviz presentations and that perceived risk is what is keeping many of the larger domes from adopting this type of programming. Components of the perceived risk include stability, performance and predictability, and strategies for improving in these areas are sketched.

1. Introduction

In this paper, I take a birds-eye perspective on live sciviz presentation technology and discuss the adoption rate of this in domes and digital planetariums. For simplicity, I will use the term “dome” to refer to both types of facilities. I am the chief executive and founder of the software technology company SCISS, manufacturers of Uniview, and as such there may be areas in this paper that are regrettably Uniview-centric.

When discussing adoption rate and strategy, it is important to understand the past of sciviz in domes. Ten years back, a year or two before I was even introduced to this industry, it was 1999. The world’s first digital planetariums were about to open. Silicon Graphics Inc (“SGI”) dominated the computer hardware industry for anything multichannel, and there were plenty of custom software solutions for sciviz but very few, if any, off-the-shelf products for sciviz in domes.

The use of SGI machines ten years ago indicates that decision-makers foresaw an extensive use of live sciviz presentation technology in their domes. SGIs by nature were built for that very purpose.

Ten years later and we have changed the hardware platform completely. A handful of PC cluster systems with off-the-shelf sciviz presentation products have emerged. We pride ourselves at SCISS at having been in the forefront of sciviz in domes for the duration of our company’s life, and we also acknowledge the great work of some of our current competitors in the field. But what are the actual adoption levels of our technology? Are we doing better than one did back in the days of SGI?

Also, looking into the crystal ball, where are we ten years from now? What will the adoption rate of sciviz presentation technology in the domes be then? What factors control the growth of this segment of the industry?

There is no doubt that the advent of digital domes have led to an increase in sciviz in the format of linear video shows we’re used to seeing in IMAX/OMNIMAX theaters – but what about live sciviz presentations? This paper paints a picture based on research done by third parties and on internal estimates done here at SCISS.

2. Live sciviz presentations

To the best of my knowledge, there is no comprehensive study on exactly how much domes use their systems for live sciviz

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presentations. At SCISS, we regularly make our own internal estimates of how much application our users find for Uniview in their programming. We do collect some limited statistics, and much information is based on what we learn from informal dialogs.

Combining our internal estimates with the enlightening picture painted by Mark Petersen at Loch Ness Productions and his State of the Dome Address (see [1]), we can start to gain an understanding and appreciation of the current technology adoption rate.

In the table below, the "size" variable simply represents different types of domes. We find that many of the smallest domes are portable/inflatable, and that many of the largest are a part of a greater museum institution.

The "live" variable is an indication, based on our own internal estimates, for what percentage of the total number of shows at a facility are live sciviz presentations. It is calculated as number of live sciviz presentations per month divided by number of total shows and presentations per month.

Size	**Live**	**Aggr. attend.**	**SV attend.**
1-9m	75%	3 429 225	2 571 919
-15m	29%	6 584 246	1 909 431
-21m	13%	16 162 006	2 101 061
>21m	2%	9 348 429	186 969
Total	19%	35 523 906	6 769 379

The "aggr. attend." variable is from Petersens's Address and represents the projected attendance to the different types of domes. Out of the stated attendance, 36% are actual survey responses and 64% are projections.

The "SV attend." finally is simply the resulting number of attendees to live sciviz presentations in domes globally. Needless to say, there may be other estimates that paint somewhat different pictures. But we can see certain obvious trends;

- The usage of live sciviz presentation tools is concentrated to small and mid-sized domes. The live ratio of the largest domes is very low.

- The total number of visitors to live sciviz presentations makes up a significant portion of the total number of visitors to domes.

The analysis of this is multifaceted. First, these are estimates and not actual research facts. This is especially true for our own internal estimates and less so for Mark Petersen's great work. Second, larger domes have tighter daily show schedules which dictate a requirement to have predictable and exact show schedules. Also, the smaller domes often have smaller budgets which make the use of live sciviz presentation software more appealing from a production and/or acquisition cost perspective.

3. The larger domes

Larger domes also, very naturally, have decision-makers with a greater distance between themselves and the daily operations – a result of more managerial duties and a larger budget to overlook. My thesis is that live sciviz software have so far not managed to convince these decision-makers that the promises and capabilities are greater than the risks. Live sciviz presentation is a new promise and capability of digital domes. It has been around for less than ten years, in a productized format. So it is only natural that it has not yet managed to convince everybody.

One way to help push live sciviz forward is to perform and publish actual studies of the audience reactions. There are at least two studies that have been performed regarding the audience response to Uniview;

- Dr. Ka Chun Yu at the Gates Planetarium, Denver Museum of Nature and Science, has surveyed adult audiences to live sciviz programming in the nighttime (see [2]). The respondents gave a whooping 4.3 on a scale to 5 on “overall satisfaction”, with 4.19 being the lowest and 4.48 the highest of 6 different presentations.

- Joel Halvorson at the Minnesota Planetarium in a portable dome, has surveyed school group audiences to live sciviz programming in the daytime (see [3]). The respondents gave an even more impressive 9.32 on a scale to 10 on “would recommend to others”.

These surveys show the promise and capability of live sciviz presentation in tools such as Uniview. Rating over 9.0 on a scale to 10 is extremely good for any visitor attraction and even better for an educational facility.

We can draw the conclusion that visitors appreciate live sciviz presentations. We also know that it is a financially sound model, as the cost per minute of in-dome programming is low.

Remaining as an issue to be resolved is the perceived risks involved in live sciviz presentations and programming.

4. Overcoming risk

Risk is about stability, performance and predictability. Stability mostly comes down to experience and time. As off the shelf products mature, stability increases. As the users grow more familiar with the tools, stability increases. Uniview and other competing solutions have gone a long way in this area, and increasingly professional training programs help too, and while it’s important to continue to emphasize stability it’s not the main area of concern at this point in time.

Performance is about features, graphical quality and creating audiovisual experiences that are good enough to not ruin the suspension of disbelief. Compared to where other technologies, such as the gaming industry, is we’re doing a decent job today. Similarly to ten years ago however, we’re quite a ways behind what the current cutting edge is in some of the other leading computer graphics industries. The dome industry has never been a leader in this field, we’ve always borrowed technology from others and the gap between us and say the gaming or medical imaging industry is more or less proportional to what part of our decision-makers’ budgets goes toward software.

Today it’s possible to get software alternatives for free that are good enough for some applications. For a few percent of a total project budget it’s possible to get a high end tool like Uniview or its competitors. But what would happen if the industry started to invest say fifteen percent of their project budgets on live sciviz presentation software.

Without a doubt, the gap to the leading industries would diminish. Such a change in budget allocation would enable domes to run more than one competing software system. Much like you run Photoshop for images and After Effects for video on your production system.

This would in turn make it possible for the companies developing software to differentiate and specialize more than we do today. To venture into certain special areas and leave other areas where a competitor is particularly strong – which in turn would lead to an overall higher performance.

So to conclude that area, the key to increased performance is about opening up domes to multiple systems, as this will enable specialization.

The third area I mentioned is predictability. In this area, it comes down to making it feasible to use live sciviz presentations in shows that have a fixed length in a tight daily schedule.

My philosophy is that the overall narrative of any given live presentation is defined beforehand. Very few, if any, presenters improvise their entire live sciviz presentation. What they do however is to leverage the power of manipulating the simulated time, the camera view and the object properties, whether it's the Jovian moon system or an Earth layer, within the context of the overall narrative.

I believe that the live element is valuable to such a degree that it deserves to be an option for also the most predictable show. I'm not suggesting every single show must have a live component. But in an ideal scenario it should be a viable option for every slot even in the busiest of schedules.

It's been possible for quite some time to script live sciviz software through text-based scripts. Through SCISS' Uniview Producer product we've created a tool that provide a graphical frontend to creating shows that are predictable in the sense that they combine linear and interactive components and run at a fixed length. It allows users to combine a linear component with a few minutes of live presentation in the middle and another few minutes live at the end.

By allowing the user to do this, but within a confined area of time and in a confined place within a linear show, we can combine the best of many worlds into a safe, stable, high-performing and predictable show that can truly blow audiences minds.

With the combination of strict timeline control over the system and live "keyframes" where the system turns interactive for a given amount of time, we've made an effort to help overcome the predictability issue.

5. Conclusion

To conclude, live sciviz presentation is a significant portion of the activities in our industry, even if the exact percentage is based on estimates and not researched facts. We can conclude that smaller domes have significantly higher adaption rate of this technology than larger domes, and that larger domes hold off to an extent because of the perceived risk involved in mixing live sciviz presentations with tight show schedules.

This risk can be countered in a number of areas, such as stability where technology and processes are already making significant headway. Another area is performance, where a key enabling factor is if the industry and the individual facilities decide to open for the possibility to use more than one system in their facilities and thereby enable specialization.

Finally, predictability is important and one approach to offer this while at the same time leveraging the power of live sciviz presentations is to enable combinations of linear and time-constrained live elements. This makes live sciviz a viable option for shows even in the busiest of show schedules.

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Immersive Dome Theater in Japan

Isshi Tabe*1

There are over fifty immersive digital dome theater in Japan. The numbers growth rate of digital theater increases year by year . The unique purpose of immersive dome theater, especially many sites originated from planetarium is for astronomical education and popularizing science. As long as the immersive dome theater standing this region, the system need next four functions. 1) night Sky Simulator, 2) Full dome "power point like" presentation, 3) full dome movie player, 4) space engine. We can choose many ways how to project full or partial on dome, single lens system or multi projector systems. Make decision will be done by consideration of initial cost they can pay, shorten life of digital equipments, running cost. In my talk, the situation of immersive dome in Japan will be discussed.

1. Introduction

If the means of Immersive Theater is equal to planetarium dome theater, we can consider it as the development of so called digital planetarium in Japan. We believe the planetarium should to be for only education and popularization of astronomy, not for entertainments. Many public planetarium in Japan are belong to scientific center or science museum, however many of them are not science oriented. Japanese planetarium has two faces for better or worse. Many professional and amateur astronomer think the planetarium in Japan is only for elementary and junior high school pupils lean constellation

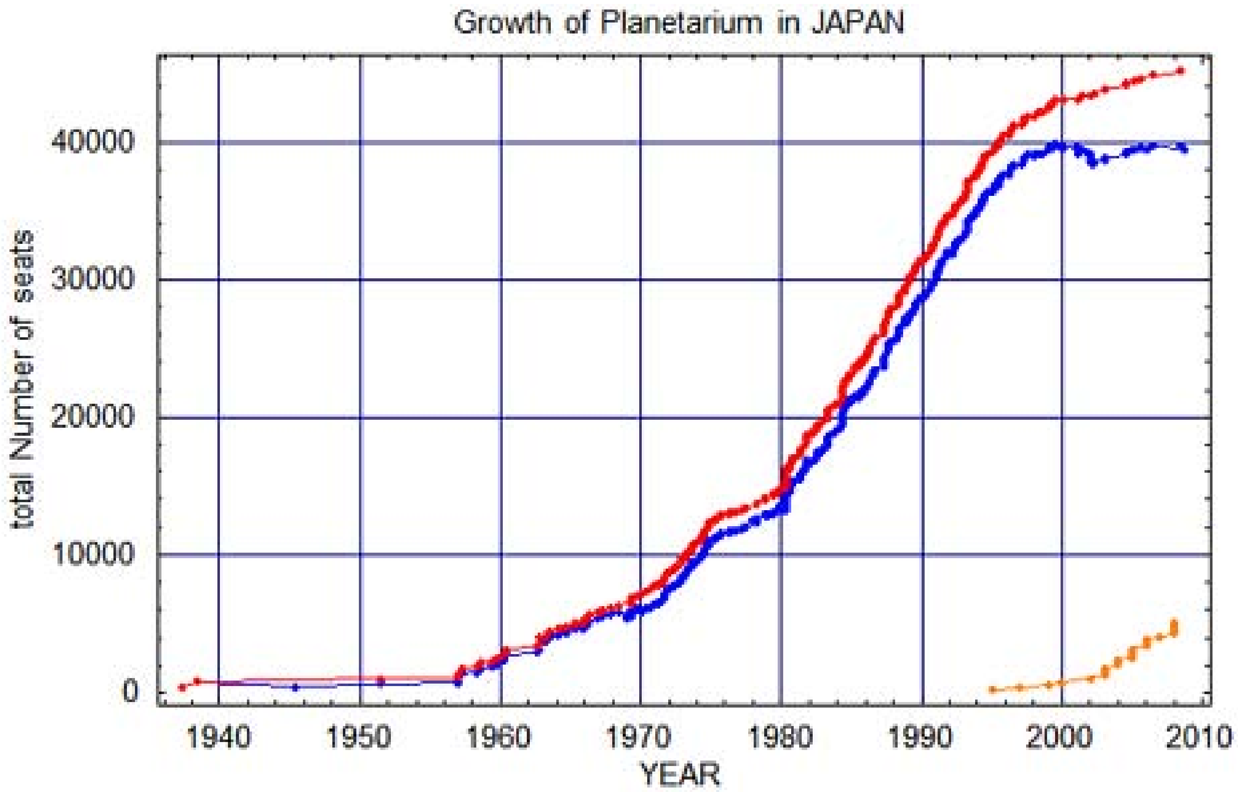

Fig.1. Growth of planetarium in Japan from 1937 to 2008. Red curve is not considered closed site. Blue curve indicates total number of seats at time. Orange curve indicates number of seats of digital planetarium.

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Fig.2. Typical "analogue" planetarium's console. Suginami Science center was opend in 1967.

tonight and mythology from Greek (surpising!). In fact many planetarium show is limited to non-science program. Many program supplier prepare non-science program rather than scientific ones. On the other hand, some astronomer in NAOJ think that the real immersive theater such as NAOJ's 4D2U theater, Synra dome of the Science Museum is NOT planetarium. If we require a counterpart of such non-planetarium of Japan to USA, we remind Hayden planetarium in NYC or Adler planetarium in Chicago. They all said that "we are the planetarium". It`s very sad for both US and Japanese planetarium peoples. In this paper we carried out the general condition of planetarium in Japan and discuss what is the immersive theater, what is digital planetarium. Tabe and Ayers[1995] also consider the political and technical situation of planetarium of mid1990s in Japan.

2. Digital Planetarium

There are 268 planetariums in Japan. This number dose not count school planetarium and small size Konica-Minolta's Media-globes, but includes three stereo dome theater in Tokyo. Notice in this number includes 26 digital planetariums. This is just 10%of whole planetariums. Ed Lantz suggests that 25-30% planetarium of in US have became digital ones.

The composition of digital planetarium is very simple. Only two instrument elements are important and the others are just extra. One of the most important instrument is video projector(s). The another is computer(s). Progress of video projector is

Fig.3. Panasonic DW-10000 projector with Togen circular fish eye lens.

very rapid and technical innovation is done every several years. People surprise the DPL projector. Same people surprise the appearance of high resolution and high contrast projectors again and again. But at now the contrast and brightness is in the relation of the trade-off, there are no product that is satisfied both contrast and brightness. But we can take optimistic consideration to this problem.

Typical bright projector is Panasonic DW-10000 projector. Although resolution is just 1920*1080p, in the reason of high luminosity, it achieve very impressive images. Furthmore bright and higher resolution projector is very popular SONY using the technology of a kind of LCOS –SXRD chips.

Fig.4. SONY SXR-T110 projector at Milwaukee Science Center. Projector's light flux is pass through the hole cleared on surface of screen.

The most remarkable projector is Victor-JVC's DLA-SH4k. The resolution is comparable to SONY

SRX-T110, however the contrast (native contrast of chip) is extremely high and have good compatibility with star field from opt-mechanical projector.

Fig.5. Victor-JVC DLA-SH4k projector. This photograph was taken at Kenji Williams's Bella Gaia event in October 2009 at Hokutopia Planetarium Tokyo.

About hardware of computer, we can point out progress is as rapid as the progress of electronic engineering especially performance of CPUs and GPUs. The future of digital planetarium is depend upon the ability of computer system. As long as the progress of hardware continue, we feel we can expect good future, but the fact depend on computer system completely has serious fault. We can point out the two mean of short life time of system. One is the life time problem of electric parts. Many people know the life time of PCs are five or six years. We know the Japanese young people change their cellular phone every two years. Some people change every year. This means second mean of short life time. As same as it is not possible to endure for them to continu to use old cellular phone, we can not imagine we use digital planetarium five years ago. Many planetarium people in Japan aware the fact short life time of digital instruments, but they still have a delusion that new planetarium can use for more than twenty years like as old planetarium of plastron.

The recent development of software engineering is marvel. In Japan, Astro-Arts's Stella Navigator has big reputation as a PC planetarium from many amateur astronomers and planetarians. It have been very happy if they could use full dome version of Stella Navigator, it is Stella Dome Professional. We can show the star field from anytime, anyplace off course any direction. It's very easy to indicate any coordinate lines, cardinal points, constellation figures and lines and daylight and moonlight, light pollusion, and demonstrate durnal, annual and precessional motions, enhanced annual parallax , enhanced proper motion of stars and more.

Although many PC planetarium software only expresses only universe view from the Earth. Stella Dome Pro can move the point of view to any place in universe. It can involve the function of so called "space engine". Main player of space engine function is Mitaka or Univew. In the software complex, as all dependent software share same user interface, user can operate it like as one completed system.

Many people use presentation tool like as Power Point in dome. Power Point is powerful for lecture in classroom, but in dome the functions are insuffic –iency, for example we can't show any panorama or all-sky by Power Point. Many people are longing for to use so-called Power Point for full dome many years. This luxurious dream come true by Orihalcon Tchnologies's the Quadratur software in 2008. Every mindful planetarium people pay attention the software complex of Stella Dome Pro including the Univew performed on the Quadrature.

3. Optical System

There are two giants in Japan. Goto Inc, and Konica-Minolta Planetarium companies have been taking an active part and continue to update their opt-mechanical star projectors. The sophisticated technologies rise up their instrument become to be comparable to the originator Zeiss. Almost 100% of Japanese planetarium are using machines from both company.

A few another company try to develop optical planetarium in 1960s. Kowa company made several machines for 10m class dome. The Nishimura a very famous middle size telescope manufacturer in Japan, try to make planetarium in 1961, but they gave up. The famous Camera maker Pentax produce a Zeiss type planetarium in 1980s for trial purposes. This machine is still working in 8m dome of Buddhist temple Shouganji in Tokyo.

The outstanding third party is a now world famous Ohira Tch's Megastar. Mr. Takayuki Ohira's story of developing his own Starball with extreme many star (the name Megastar is caused by two million stars) is very popular and many magazine and TV in Japan cover them.

At first the Megastar is not for a permanent use, but the simple structure and natural star field, milky way and its topicality admit gradually, some planetarium has made decision to introduce Megastar for their main projector.

The Stella Dome Pro can control Megastar easily. Megastar become factual an element of software complex we regard previous clause. We have to develop new style of planetarium of next generation considering education for astronomy and other science. .

5. How should we do?

In many Japanese planetarium of science museum, there are few astronomer or real science educator. This fact should be surprise. As we point out in introduction of this paper, Japanese planetarium has many discrepancy. Why are these discrepancy come up? In some planetariums, there are no person who received appropriate education and training. A few part-time operator only push a start button at every show. Their term of office is five years from three years. The example of not disturbing the reappointment is few. With this, it is impossible to expect a high-quality educative effect in planetarium activity. On the other hand, the young person who studied astronomy at the university is embarrassed with finding employment.

Japanese planetarium should change their appointment system that search for good educator. As the assumption, an increase of planetarian's capacity is hoped for. We consider that now is the best opportunity though we completely change skill in the age when the world changes from the analogue to digital. Talent who has a skill different from a current skill is necessary for mastering the function of a new planetarium. As for a digital planetarium, it is very important up to now that the person in charge of human affairs understand the difference. There is no pursuer license in the planetarium now.

This is very complex political matter, but someone have to make some standards immediately. Now is the time to start action with well experienced planetarium people.

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Chapter 4

Hardware and Software Development

Infitec™ Stereo System for Synra Dome at Science Museum Tokyo

Kiyonobu FUKUSATO *1

Barco has installed world first Infitec stereo(3D) iDome system at Synra dome of Science Museum Tokyo in March 2009. This document describes the outline of the system and features of Infitec stereo in comparison with other type of stereo solution.

1. Introduction

Barco is a international company, headquartered in Kortrijk, Belgium with global presence in over 90 countries, and is manufacturing professional visualization and display solution. One of Barco's unique solution is full dome display system for digital planetarium including stereo (3D) by utilizing multiple projectors.

2. The Method of Stereo (3D) Image

There are 3 different types of method for stereo (3D) image display and each of them has pros and cons which are described in the Table 1 below.

	Pros	Cons
Active stereo	-Screen Independent -Good stereo separation -Can be realized by one projector	-Need emitter to synchronize -Glasses are rather expensive -Unsure if glasses are working
Passive (Polarizing) stereo	-Low cost glasses and light weight -Easy to make system with any projectors	-Screen dependent (need polarizing screen) - Needs always tow projectors
Infitec Stereo	-Screen independent -Good stereo separation -Can be chosen either active and passive	-Low light efficiency -Glasses are rather expensive - Need color difference compensation

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3. Main Features of Barco Infitec iDome

Main features of Barco Inftec iDome are as follows;

1) Accurate system design such as positioning and blending by dedicated Barco SimCAD™.
2) High quality of stereo image by built-in Infitec stereo switcher which also enable switching of mono and stereo image.
3) Built-in DynaColor™ function which enable to compensate the color difference between left and right image of Infitec filter.
4) Dedicated optical blending plate to eliminate double black.
5) Projector build-in high performance Warping function to reduce peripherals and the load of image generator.

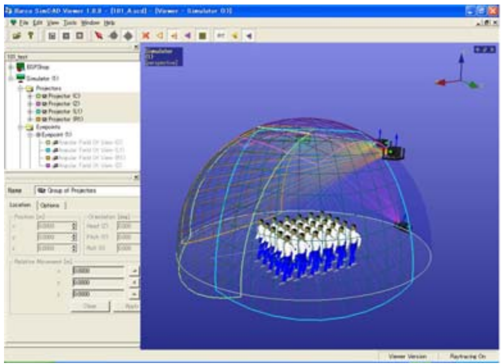

Fig 1. Barco SimCAD

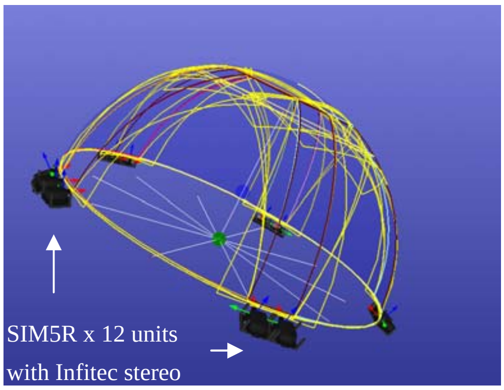

Fig 2. Projector layout of Synra dome

4. The Projectors

In the Synra dome, 12 units of Barco single-chip DLP projector SIM5R with Infitec option are used. Table 2 shows the main features of SIM5R.

Item	Specification
Display device	1-chip DarkChip DLP
Resolution	SXGA+ (1400x1050)
Brightness	2500AL (4000AL with RGB CW)
Contrast Ratio	2000:1
Lamp	2x250W UHP
Weight	13Kg
Dimentions	W415xH195xD565

Table 2. SIM5R main features

Photo 1. Barco SIM5R projector

5. Infite™: How it works

As shown in Fig. 3, two different characteristic of Infitec filter can separate images of left and right eye by wavelength. Same characteristic Infitec filter are used for inside of projector and glasses.

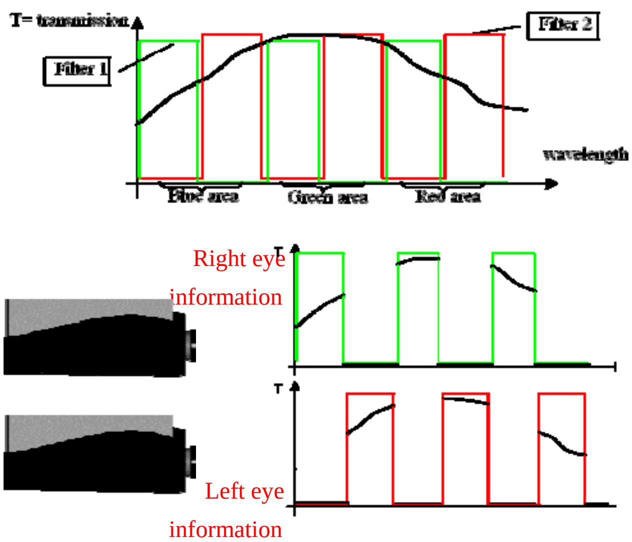

Fig. 3 Left and right eye image separation by Infitec

6. Infitec and Color

In principle, color gamut different exists between left and right eye channels with Infitec technology. This is especially visible in saturated color. Therefore it is important to compensate the color space of left and right images. Barco's DynaColor function can create identical color triangles as shown in Fig. 4.

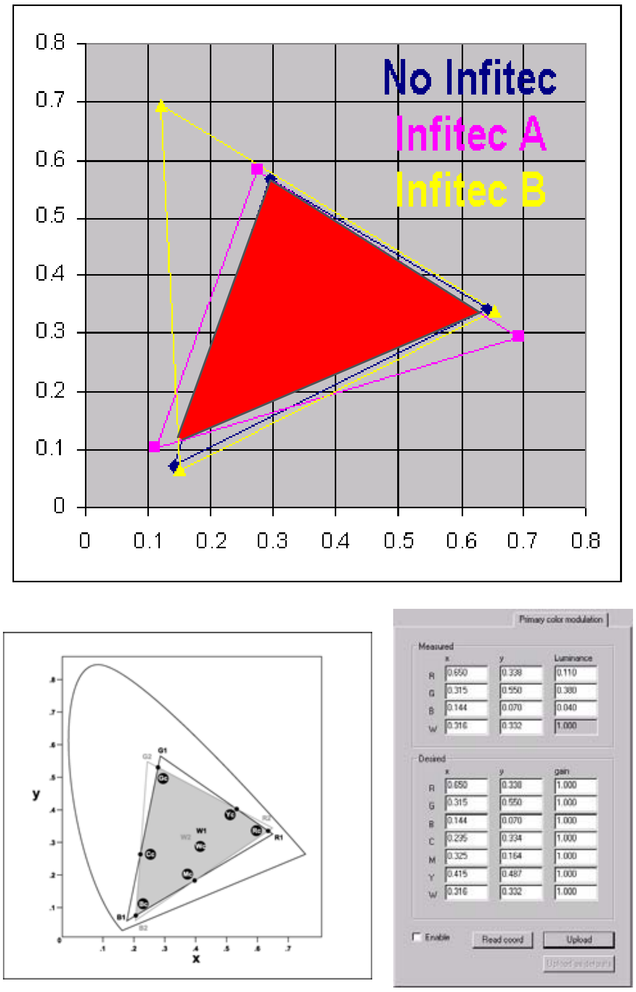

Fig. 4 Infitec color space and DynaColor

7. Infitec Stereo Glasses

There are 4 different types of Infitec glasses as shown in Photo.2. Main difference is a size of Inftitec filter which differs the viewing angle as well. The bigger the filter size, the higher the price.

Low cost model

Middle class model

Standard model

Delux model

Photo 2. Infitec Glasses

8. Optical Soft Edge Matching (OSEM)

In the planetarium application, black level is important because most of contents are universe related. Until several years ago CRT projectors had been used for planetarium and black level was not issue but in case of light bulb projector like SIM5 black level is becoming one of major issue. When two images of two projectors are blended (overlapped) blending area is becoming more brighter than other area because of so-called double black effect. Barco is making dedicated design of optical blending filter for each dome system to eliminate the double black effect. The Fig. 5 shows the dedicated design by Barco SimCAD and Photo 3. and 4. shows making original blending plate and installed in front of projector.

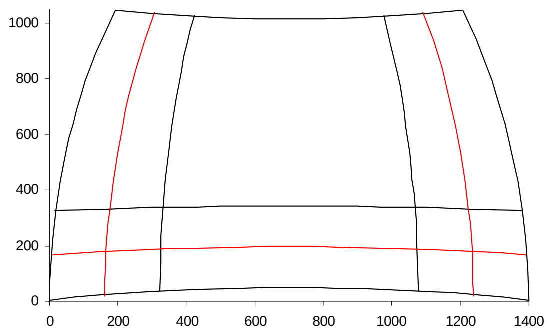

Fig. 5 Dedicated design by Barco SimCAD

Photo 3. Making original blending plate

Photo 4. Blending plate installation to projectors

9. Installation and Alignment

When install projectors in the dome, the positions of each projector are very important. Barco SimCAD, is automatically calculating the positions of each projectors. In order to align images of each projectors, Barco is using Laser Diode Array shows in Photo 5. By those technologies, seamless and excellent images can be realized.

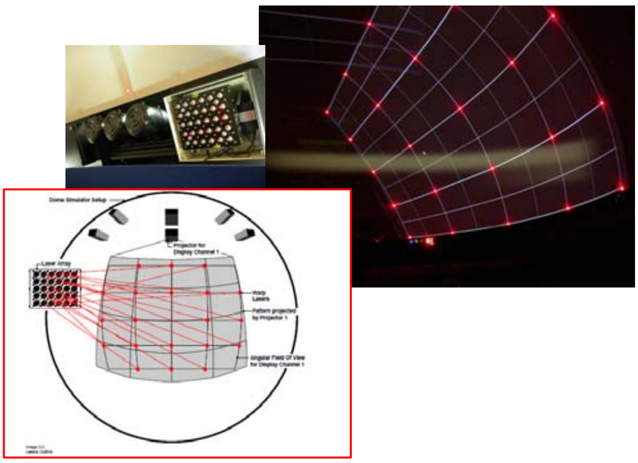

Photo. 5 Laser Diode Array

10. Conclusion

When you see the stereo contents of universe like 4D2U or Uniview in the Synra dome, you feel as if you are in the infinite universe although dome diameter is only 10m. We are hoping that many of similar system will be installed at many places worldwide and many of small kids enjoy the contents and make dream by them.

The new style of digital planetarium, from field use to dome projection

Haruki KAMIYAMA[*1]

In Japan, many amature and professional astronomers, planetarians uses Japanese de facto standard astronomy simulation software StellaNavigator regularly since it was first developed and went on sales seventeen years ago. StellaDome Professional is a evolved edition of StellaNavigator and you can project beautiful sky view onto a large dome-type screen.

I will talk about this evolutions of the series of advanced astronomy softwares not only for personal use but also for the large scale institutional purposes.

1. For every sky watchers

Since 1991, we have been developing and selling `StellaNavigator' in Japan. StellaNavigator is a computer software for astronomical simulations. As a tool for practical star watching, StellaNavigator has been receiving high appreciation from both professionals and amateurs.

Through the development of StellaNavigator, we were especially careful to display the sky as accurate and beautiful "as we see". For example, the software calculates positions in topocentric coordinate, so we can simulate solar and lunar eclipses precisely. Atmospheric effects are also taken into consideration; Canopus, which barely shows itself in the southern horizon at Tokyo, is displayed as a reddish 2nd magnitude star. Additionally, the growing data of newly found objects (comets, minor planets, supernovae, etc.) can be updated via the Internet.

These features lead to the common usage of StellaNavigator in astronomical education at school. Today, even the official curriculum guideline recommends astronomical simulation as a tool.

2. fSupport for usage in planetarium domes

"StellaDome Professional" is a software based on StellaNavigator, and can project sky-images on and around planetarium domes. It is a unique spin-off from a consumer software that manages to work in any professional use, from fish eye lens to multiple projectors.

We started installing StellaDome on planetariums since 2006. Today it is used at 3 permanent domes and 1 transferable dome.

As you can see, our digital planetarium softwares are now widely used at observatories, schools, homes, and planetariums, thus contributing to make astronomy popular.

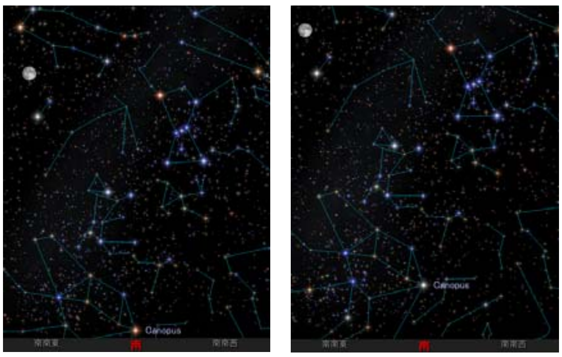

Fig.1. left: Canopus is a red star in Tokyo. Right : Canopus is a bright star in Okinawa.

Fig.2. "StellaDome Professional" was installed at Hiratsuka City musium in 2006.

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3. Other platforms

At home or school, one can learn about stars through computer simulations, and at a planetarium, experience star-gazing in virtual starry skies.

But is that enough?

If a beginner would try to watch stars under the real sky, information from planetariums aren't practical; there's no guidance for directions, and the stars move with time. For them (and every star lover), portable digital planetariums would be a great help.StellaNavigator works on computers, and laptop computers, despite their scale-down evolution, is still not something that can be carried anywhere with ease.

Therefore, we developed "iStellar", a planetarium application for iPhone. You only need to set the location and time to see a beautiful starchart. (Fig.3)

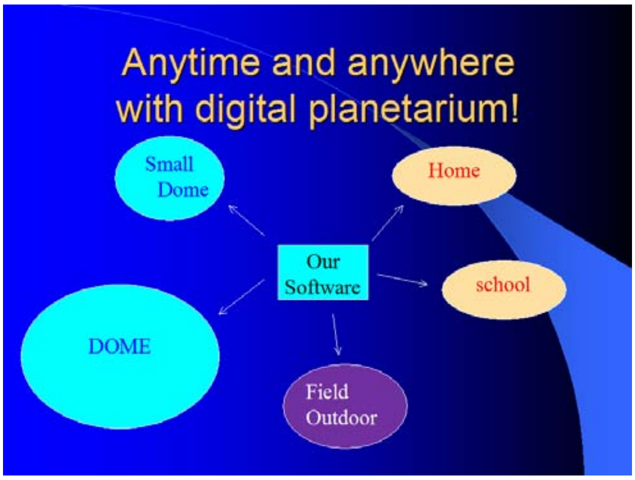
Fig.3. "iStellar" is a compact software for iPhone,.

Our next step was even more innovative; "Hoshizora-Navi", a software for Nintendo DS, the popular portable gaming hardware. The cartridge contains a 6-axis sensor, and by holding the DS towards the sky, what you see in the sky will be in the screen. Even beginners with poor sense of directions can find constellations right away. (Fig.4) We believe that finding constellations under the real sky is an important step in learning astronomy.

4. Conclusion

Now we can create a virtuous cycle for astronomical education: first learn the basics at a permanent planetarium, then go out to see the real sky with the aid of a portable planetarium, and back to the big one to learn more.

Fig.4.DS Hoshizora-Navi is a software for Nintendo DS series with 6 axis sensor..



4K Transmission Experiments at Keio DMC

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We, Keio DMC, have tried several experiments related to 4K networking applications. In this paper, we briefly explain what 4K is and why 4K requires networking. Then, we introduce our three experiments based on the expected applications. One is 4K network distribution, one is 4K networked production, and the other is 4K videoconference. These experiments were tested over International communication networks and showed not only its concepts but also its feasibility. Finally, we discuss the similarity between 4K and dome theater applications. Dome theater presentations also need a quite big image size due to the huge screen size. Sometimes, it is eight times bigger than 4K. The networking technology developed for 4K can be used for easy content production. On the other hand, dome theaters are at the turning point to change their systems to digital from the point of business. It opens up new services called alternative content like live broadcasting of natural phenomena using network.

1. Introduction

Recently, digital technologies have rapidly grown up and we are able to handle higher quality medias than the existing broadcasting services even on our computers. Among them, we, Keio DMC [1], have focused on Super High Definition images called “4K”, which has 8 million pixels on a single image, and tried to find the applications through several experiments for last five years.

We first started from capturing and displaying of 4K images, then tried production using 4K camera and distribution of 4K content. For example, at iGrid2005, we transmitted 4K live images from Keio to University California at San Diego (UCSD). In early summer of 2007, we captured an opera stage by 4K uncompressed recorders at Amsterdam, and transmitted the show to San Diego with 4K JPEG2000 compressed images and 5.1ch surround sound. In 2007 winter, we also tried 4K uncompressed transmission of Kyoto Prize Ceremony from Kyoto to Stockholm. And, last December, we demonstrated a 4K videoconference between Tokyo and San Diego.

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In this paper, we briefly explained the spec of 4K images and its demands for networking in Sec. 2. Sec. 3 describes our 4K networking experiments. Sec. 4 discusses the dome theatre applications using networks and we conclude in Sec.5.

2. 4K and networking demands

A. 4K data size

4K is an alternative name of Super High Definition image which has about eight million pixels on a single image. It is roughly four times larger than High Definition (HD) image. More precisely, there are two types of 4K images in terms of pixel counts. One is Quad HD (QHD), which has 3840x2160 image size. And the other is the “4K”, which has 4096x2160 pixels, defined by Digital Cinema Initiative (DCI) in 2005. In this paper, we use 4K for the term which covers both QHD and “4K”.

4K image has quite huge data size. For example, data size of single 48bit/pixel (16bit for R, G, and B) 4K color image reaches to 50MB. In order to make motion pictures, we need 24, 30, or 48 frames for one second in regular cases. Two-hour-movie consists of hundred thousands files and its entire data size is about 10TB. This size is only for the final master files. It is said that the number of files created in the capturing process and the middle of the production process are tens times of the final master files. Thus, we have to handle millions of 50MB file for 4K motion pictures.

4K video streaming also needs huge bandwidth. In general, the required bandwidth depends on the color encoding, bit depth, and frame rate of video streams. However, in video industry, uncompressed HD digital video streams are realized by standards called HD-SDI, whose transmission is fixed rate like 1.5Gbps or 3Gbps. In order to keep transparency of video streams signal between before and after the video streaming over network, we need 1.5Gbps or 3Gbps bandwidth for HD uncompressed streaming. Therefore, 4K uncompressed streaming needs 6Gbps or 12Gbps. The required bandwidth for compressed streaming of 4K depends on the compression algorithms. JPEG2000, which is the standard compression in DCI specification, requires about 500Mbps. H.264 can reduce the bandwidth to about 100Mbps.

B. 4K applications on network

We discuss three major 4K applications over network here. One is content distribution, one is distributed post-production, and the other is video communications.

4K contents distribution is straight forward networking application. Since we can transmit higher quality of images using 4K, it is worth looking at even when we show the images in large-scale venue. We can categorize 4K contents for distribution into two types. One is pre-processed content including digital cinema. Network release of new cinema clips and on-demand cinema viewing are the examples. The other type is live content like sports events, theatrical plays, musical concerts, etc. Especially, the second type is called alternative content or other digital stuff (ODS). Distribution of alternative content through network is creating new market. For example, New York Metropolitan Opera has started to distribute their theatrical play to the world with HD video and makes a profit. Live stereoscopic 3D distribution of big sports games have already started and it is also profitable business. Although these transmissions are using HD right now, we can realize much higher quality with 4K.

Distributed post-production will be more important for high quality content production. Currently, even the images are HD (the total size is quarter of 4K), the post-production houses store the data in portable HDDs and send it to their directors by postal services for image checking. However, this postal delivery method has one big drawback. It takes long time. First, at sender side, it takes time to copy the data from their storage to the portable HDDs (usually it is USB access). Second, physical delivery takes time. International delivery is widely used because post-production houses distributed over the world and sometimes it takes a week. Third, the copying from the portable disks to storage at receiver side for the further processing takes time due to the slow access speed of portable HDDs. These transfer delays make production be prolonged and it creates unnecessary costs. Therefore, immediate data exchange between post-production houses and directors using communication network are desired even the data size is huge.

Video communication is the third application. Existing major communication methods are text messaging like e-mails and messengers and phone calls. In addition to those communications, video communication is widely adapted in our daily lives according to the deployment of computers with embedded camera. Every half year, new models of still camera and video cameras using the newly released CMOS sensors. The number of cells of image censors is growing up year by year, and seven million pixels are already achieved. Therefore it is not so difficult that we use 4K capable image sensors in near future. The 4K capable video cameras realize more detailed image capturing and give us the realistic expression on displays and on screens. In 4K video communications, we can feel tiny changes of expression on our faces through videos.

3. 4K transmission experiments

We describe our three 4K transmission experiments expected to be the applications showed in the previous section.

A. 4K JPEG2000-compressed streaming from Amsterdam to San Diego

The first experiment was an example of alternative content. We showed that the 4K streaming opera stage satisfied audiences even behind the network.

Fig. 1 Live 4K JPEG2000 compressed streaming

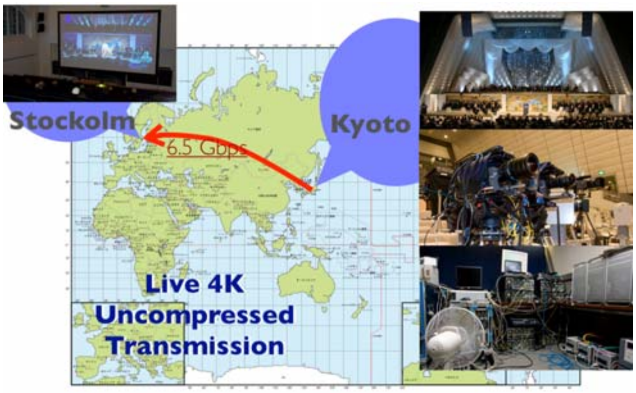

Fig. 2 Live 4K remote recording

In June 2007, we transmitted an opera stage from Amsterdam in Netherlands to San Diego in California, U.S.A using 4K cameras (Fig. 1). We set up two Olympus 4K cameras, which are not commercially available, in the backend of audience seats and transmitted one 4K camera image to San Diego by NTT JPEG2000 4K CODEC.

One camera is for close-up shot (CAM1) and the other is for entire stage shot (CAM2). We initially assumed that CAM1 could capture the image as we saw from the seats in the hall. Although the captured images were almost the same with what we could see by our eyes, we noticed more close-up images were desired in video. While the show, we were receiving the advices from San Diego, where the people were looking the show transmitted from Amsterdam in front of 400 inches screen. According to their comments, human size shall be the half height of screen, camera movements must be the minimum, and the images on screen causes a sensation.

We used several international research networks from Amsterdam to San Diego. We provisioned 1Gbps network from the venue close to the Amsterdam central station to University California San Diego (UCSD), CALIT2. Actual traffic rate was varied time by time because the JPEG2000 is frame-by-frame encoding. Our target rate was about 500Mbps with 6ch PCM audio. The delay between Amsterdam and San Diego was about one second.

B. 4K uncompressed streaming from Kyoto to Stockholm

The second experiment is an example of networked production. We demonstrated possibilities of network recording.

In November 2007, we transmitted 4K uncompressed images of Kyoto Prize from Kyoto to Stockholm (Fig. 2). We prepared two 4K cameras and 4K uncompressed transmission boxes at the venue in Kyoto. Two cameras are for close-up shot and for wide-view.

The bandwidth for 4K uncompressed streaming needs over 6Gbps (the camera signal is YPbPr 4:2:2). Therefore, we prepared 10Gbps network from the venue at Kyoto to KTH in Stockholm. It went from Kyoto to Stockholm via JGN2plus, StarLight, CESNET, NetherLight, SURFnet and NORDUnet. The video signal directly went into the uncompressed transmission boxes and was transmitted to Stockholm. At Stockholm, we prepared 4K uncompressed receiver boxes, and received the video signal. The video cables from the receiver boxes were connected to a recorder box, a 4K projector and a 4K LCD. We successfully transmitted the image to Stockholm.

The impacts of remote recording using uncompressed streaming are as follows. 1) We can avoid the problems caused by uncertain local conditions such as storage size, disk failure, power, and air-conditioning. 2) We can use the recorded video just after the transmission or even while the transmission at remote side. 3) We can make multiple backups during the transmission using multicast function inside network. Generally speaking, backup process takes time and it is stressful operation for the recording engineers.

In this demonstration, we also tried uncompressed video switching inside network. Video switching is usually realized in video domain not inside network because usually the two (or more) video signals at one site. However, if video cameras are located different places, then we are not able to switch between them otherwise we transmit all the signals to one place. It requires a lot of bandwidth to transmit all the uncompressed video signals to one place. In order to avoid this too much bandwidth consumption, video switching inside network is required. In fact, the available bandwidth from Kyoto to Stockholm was 10Gbps. So, we don't have enough bandwidth for two 4K uncompressed transmission.

C. 4K/HD videoconference connecting Tokyo, San Diego, and Chicago.

The third experiment is 4K videoconference. Since 4K has about eight million pixels on a single image, we can transfer much more information than SD or HD video. 4K cameras can capture not only our gestures but also our tiny movements. Usually, when we have a face-to-face meeting with somebody, we always pay attention not only to his words but also to his gesture, eyes, all of his movements. More the topic of the meeting is sensitive, more the every tiny movement is important to decide what to say next. 4K is a big candidate right now to improve the quality of video meetings.

In December 2008, we tried 4K and HD mixed videoconference among Tokyo, San Diego, and Chicago (Fig.3). We prepared 4K cameras at Tokyo and San Diego, and HD cameras at Chicago. Persons in Tokyo and San Diego can talk each other over 4K video meeting system. HD quality videoconference systems are available between Chicago and Tokyo, and Chicago and San Diego. We used NTT JPEG2000 CODEC machines as transmission units for this experiment.

Fig. 3: 4K videoconference

4. Dome theatre networking applications

Our recent activities in Keio DMC were mainly focused on 4K. Currently, 4K is a technology to show images on a flat display and it is different from dome display. However there are significant similarities between them.

First, we discuss from the technical viewpoint. The data size of dome theater image is more than 4K. Although the pixel counts which requires for the show depends on the dome size, it is said that 8000x8000 pixels are desired. It is eight times larger than 4K. Therefore, the production process requires much more computer resources and storage resources. In order to realize cost-effective production for dome theatre, we might be able to extend our networking approach.

From the application viewpoint, there has been no application except for planetarium in the conventional dome theaters. After the digitalization of planetarium, dome theaters have to find out new applications from the following reason.

It is quite similar situation to the cinema industry. Cinema industry has used film projection system for long years and now is migrating to digital projection. It is said that the ownership cost of digital projection system including installation and operation increases 200-300% higher than the film over 25 years. Therefore, they are trying alternative contents to maximize the utilization of digital projection system in their theaters. Their alternative contents are live sports and live stage broadcastings.

Big alternative contents for dome theaters might be the live natural phenomenon broadcastings. For example, total solar eclipse, aurora, and nature's wild life itself.

5. Conclusion

In this paper, we described what 4K is and why 4K requires networking. And, we showed our major activities for last three years. Finally, we discussed the expected dome applications using networks.

References

[1] Keio University, DMC: more activities are available from our site http://www.dmc.keio.ac.jp/.

Introduction to immersive projection display : DLA-SH4K projector

Hideo KUROGANE [*1] ,Ichiro NEGISHI [*2] and Tadashi YANO[*3]

We have developed new projection display (DLA-SH4K) with liquid crystal on silicon device(D-ILA^{TM}). High resolution as 4096x2400 is considered by human eye resolution and high contrast ratio as 10,000:1 are good enough to create images for various kinds of immersive image applications such as full-dome system, 3D applications etc. Also this projector is suitable not only for research application, but also for practical applications because of special features.

1. Introduction

Demands for large scale and high quality images to realize immersive images (what you see is what it exists in front of you) are increasing. Thanks to recent computer technology, we can generate high resolution images easily.

To achieve "immersive" display, we need to consider human eye characteristics. Maximum visual acuity is known as 1 minute, and its range of vision is around 40 degrees. 2400 lines and/or pixels are required. Also, focusing contrast ratio, display need to cover its brightness from sunlight (10,000 lux) to star light (0.01 lux).

Following sections describes basic technology focused on resolution and contrast ratio, and DLA-SH4K projector which covers both technologies.

2. Display device (D-ILA)

D-ILA is a kind of LCOS (Liquid crystal on silicon), which uses Single Crystal Silicon LSI (Large scale integrated circuit) technologies, and can realize large number of pixels, small pixel size, and high aperture ratio together. Also we applied vertical aligned liquid crystal structure, it makes higher contrast ratio. [1] We developed new 4096x2400 resolution D-ILA device to establish DLA-SH4K.

Table 1 shows detail specification of new D-ILA device.

We designed and established D-ILA device since 1998, and we applied new design to achieve small pixel structure and higher resolution for DLA-SH4K. . Figure 1 shows cross section structure of pixel electrode.

Resolution	4096x2400
Pixel electrode	6.8 microns square
Display area size	1.27 inches diagonal
Contrast ratio	20,000:1
Aperture ratio	93% (pixel gap 0.25micron)
Liquid crystal	Photo-stable (non-organic) vertical alignment
Response time	4.5 milliseconds

Table 1. D-ILA Device characteristics

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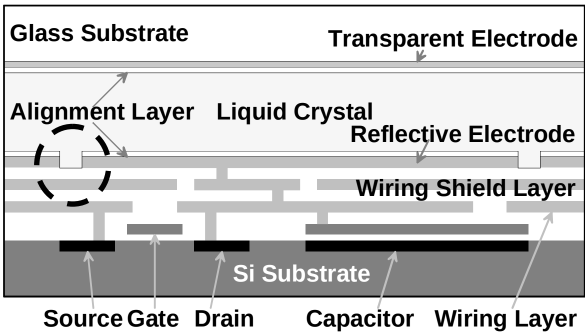

Fig.1. Cross section of pixel structure

D-ILA device consists of (a) crystal silicon backplane including scanning circuits, pixel transistors, capacitors, and reflective electrodes (b) glass substrate, and (c) Liquid crystal. Glass surface and pixel electrode have non-organic alignment layer in their surface. Image information (pixel data) are converted to pixel voltage, and set into capacitor of each pixel by pixel transistor. Projection light is coming from top side toward bottom in figure 1, reflects at pixel electrode. Incident light is modulated by liquid crystal, following to pixel electrode voltage.

Advantage of D-ILA is that we can locate transistor and capacitor at the back side of pixel electrode, but we have to design structure to prevent from strong incident light leakage into pixel transistor.

Incident light comes from pixel gap, and going through the path between metal layers with multiple reflection.

To achieve minimum effect of strong incident light, we applied (1) narrow pixel gap for smallest openings and (2) light blocking layer structure and transistor layout for maximum light path to transistor.

Focusing contrast ratio on liquid crystal device, we have to minimize liquid crystal alignment disorder in order to eliminate light leakage of black state..

Liquid crystal molecules are located following to alignment layer. At uneven background location such as pixel gap, liquid crystal is small disorder state. (shown dash circle in figure 1.) This disorder makes small light leakage but big enough to achieve 10,000:1 contrast ratio. By making pixel gap to be flat enough as pixel electrode by filling pixel gap and flattening process. We minimize the disorder and improved contrast ratio as 20,000:1 from 5,000:1.

3. Optical design

Liquid crystal projection systems need good P and S polarization control and separation. Conventional projectors use lead-contained bulk glass materials such as PBS (polarized beam splitter). Bulk glass has disorder of refractive index control, and bigger incident light angle dependence. So it has limitation to achieve higher contrast ratio.

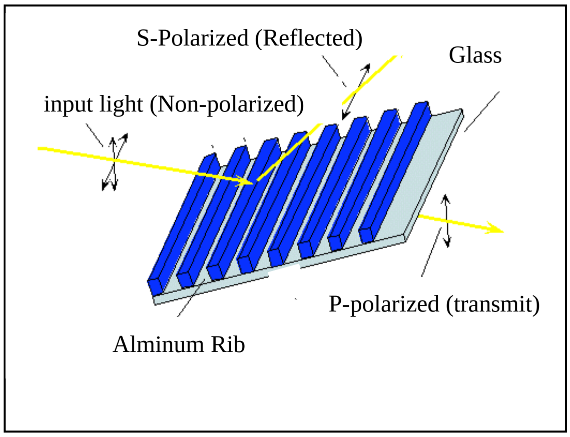

Fig.2. Wire grid structure

Figure 2 shows wire grid structure. [2] Wire grid structure is non-organic reflective type polarizer, and has aluminum ribs as 10s nanometers width and hundreds nanometer pitch on glass material.

Wire grid polarizer is located in front of D-ILA device in each color). Its incident light angle dependence is smaller than conventional PBS in visible light bandwidth. This makes to minimize light leakage into projection lens in black image.

Figure 3a and 3b shows comparison of transmittance in various incident light angle between (a) wire grid and (b) PBS.

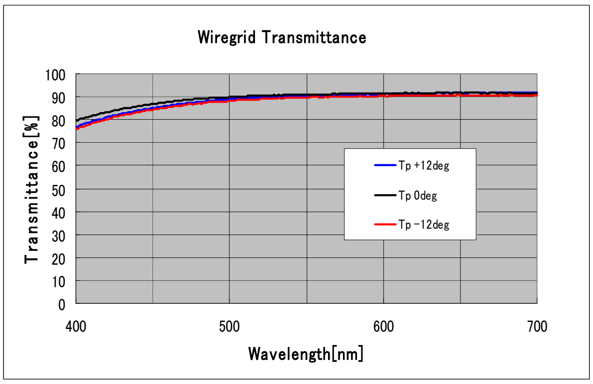

Fig. 3a. Wire grid transmittance dependence

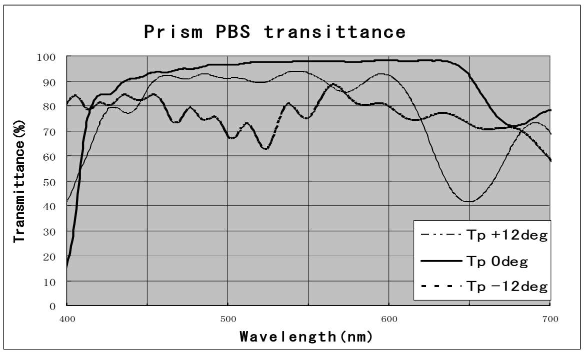

Fig.3b. PBS transmittance dependence

In case application such as planetarium, we have images with dark background and bright area / spot in single image.

Angle independence characteristics of wire grid help to eliminate ghosting and flare of bright spot in black background, i.e. good ANSI contrast ratio.

Wire grid has good enough reliability against strong light because of non-organic material, and also good for environment because of no lead material.

We use three pieces of wire grid polarizer in red green and blue optical path in DLA-SH4K, and achieved contrast ratio as 10,000:1 together with D-ILA devices.

Reviewing human eye and environment contrast ratio (sunlight to starlight), we need one million to one. We are studying to achieve extremely-high contrast ratio projector.

To project high resolution images, also projection lens performance is important.

We designed new projection lens considering required line pair characteristics (SH4K: 80 lines pair / millimeters, double as 720p, x1.5 as FHD) as well as minimized ghost and flare performances.

4. Projector specification and features

By combining new D-ILA devices, wire grid optical structure and new projection lens, we established DLA-SH4K as 4096x2400 resolution and 10,000:1 contrast ratio with brightness as 3500 lumens by 825W Xenon lamp. It is possible to observe distance of objects in pictures even in conventional two-Dimensional images, and we can feel what we have as it is by 4K resolution and high contrast ratio.

Table 2 (next page) shows detail specifications of DLA-SH4K projector.

DLA-SH4K has not only high resolution and high contrast ratio, but also has following features to realize various kinds of projection applications, especially immersive ones.

1) Four DVI-D input

DKA-SH4K has four DVI-D video input, supporting 12 bits capability. We can choose various kinds of combination of image area and DVI inputs such as quadrant, synchronize 4 images and dual images.

2) Lamp power control

We can control lamp power from 80% to 100%. It helps to adjust brightness with two projectors in 3D applications without losing contrast ratio.

Display device	3x 4k2k D-ILAs
Resolution	4096x2400,RGB
Contrast ratio	10,000:1
Brightness	3500 lumens
Lamp	825W Xenon
Input	DVI-D(dual link) x 4 (dual link, 12bit) *4
Weight	59kg (including lens)
Dimension	663x803x362 (mm)
Power consumption	100-240V 1.5kW
Tilt angle	+/- 90 degrees
Projection lens	80-300 inches, exchangeable short throw (1.1:1) and zoom (1.5-1.84:1)
Lens shift (zoom lens)	+/-50 %. Up/down +/- 25% left/right
Stack setup	possible

*4 External HDSDI converter available

Table 2. Specification of DLA-SH4K projector

3) Light weight

59kg weight with projection lens helps running with vibration environments such as flight simulators. For experimental use, it is easy to place any place.

4) Power inlet capability

DLA-SH4K has capability of AC100V to 240V (single phase) with 1.5kW. It is easy to operate in conventional ball room etc.

5) Wide Tilt angle

It helps applications such as dome theaters, rear projection in small room.

6) Exchangeable lens.

User can design special lenses, such as fish-eye lens and wide angle lens etc.

7) Lens shift function

Wide range of lens shift function helps to adjust projected image to match screen area, and easy to adjust display area of two projectors.

8) Stackable design

It helps three-dimensional image configuration with two projectors. (Left and right images for each)

There are several kinds of methods to realize three-dimensional application, DLA-SH4K can support all of them.

In case projecting two images together, It gets double brightness.

9) Mechanical pixel shifting function

We applied mechanical pixel shifting function with 0.1 pixel step in DLA-SH4K. This helps precise convergence adjustment in case of emergency.

10) Network control capability

Adjustments such as focus, zoom, color and input conditions are set by web browsers connecting by ether wired network, USB or RS232C. (No need special control software)

DLA-SH4K has own IP-address (changeable), two web browsers in one PC can control two DLA-SH4K projectors.

We designed these features to consider actual applications of higher resolution large display in practical use.

5. Conclusion

With combining and optimizing D-ILA technology and wire grid structure together, we established DLA-SH4K projector which realizes high resolution as 4096x2400 and high contrast ratio as 10,000:1 together in big screen as 300 inches. It helps to support practical immersive applications such as full dome theaters, simulators, 3D applications etc with various special features.

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Development of a 2.4K Full Dome Projection System using a fisheye lens, SUPER MEDIAGLOBE II

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Mitsuaki Shimo*2, Akira Fukushima*2 and Hiroaki Ueda*1

SUPER MEDIAGLOBE II(SMG II) is the first 2.4K full dome LCOS projector with a fisheye lens. It projects immersive stars and astronomic objects on the jet-black background. Its very high contrast ratio of 10000:1 in native and resolution of 2400 pixels in diameter can render what defies description; such as absorption nebulas or even cosmic background radiation of 3K! One fisheye lens projects perfectly seamless image from dome masters without slicing process by computers. Distortion, spherical aberration and chromatic aberration of the lens are well corrected using anomalous dispersion glass with multi coating. It provides clear images close to the optical star ball images onto the dome up to 15 meter or larger in diameter. Mitaka data base and user friendly interface for easy operation are embedded. Users can program 3D space travel, historical constellations and so on. Technical specifications and their performance are reported.

1. Introduction

Full-dome digital projection systems have been introduced to planetariums since MEDIAGLOBE or other digital projection systems entered [1]. Some systems use plural projectors, usually two to six, to get higher resolution and brighter image. Adjustment and maintenance of multiple projectors is not easy because brightness, torn or hue differ from projector to projector and brightness decreases due to temporal change of the lamps.

Single lens projector has advantages to these issues comparing multi-projector system. Full dome projectors use the image source called dome master that has circular shape. Single lens system simply projects this source but multi-projector system requires slicing and compensation process. Real time processing needs a lot of computing power and cost even now that computers have higher power than ever.

The authors have proposed MEDIAGLOBE, MEDIAGLOBE II and SUPERMEDIAGLOBE based on the policy of the advantages of single lens projection system as shown in table 1. In this paper the latest product SMG II is reported.

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Table 1 Production line

	Release	Resolution	Contrast
MEDIAGLOBE	2000	1000	350:1
MEDIAGLOBE-Lite	2003	1000	350:1
SMG	2005	1500	1500:1
MEDIAGLOBE-II	2006	1024	800:1
SMG-II	2008	2400	10,000:1

Resolution: pixels in diameter

Contrast: native

2. Requirement for full dome projector

It is reported that the best position in movie theaters is the point where the viewing angle of the screen is 45 degrees. The viewing angle of one pixel on the screen from the best position is calculated 1.3 minutes where conventional projector has 2048 pixels in horizontal.

On the other hand, the angle of the dome screen from the center is calculated 4.5 minutes where 180degrees divided by 2400 pixels which is the image diameter of SMGII. Effective viewing angle is assumed about 3 minutes because the observing distance is larger than the radius where the best position in the horizontal dome theater is the point of one third of the diameter from the back end of the dome and 1.6 meters lower side of the edge of the dome. See fig.1. The angle does not depend on the dome size but the resolution.

This value is larger than that of movie theater but it is enough for dynamic vision. Full dome theater shows much information for peripheral scene other than central fossa and that can provide strong visuals for audience.

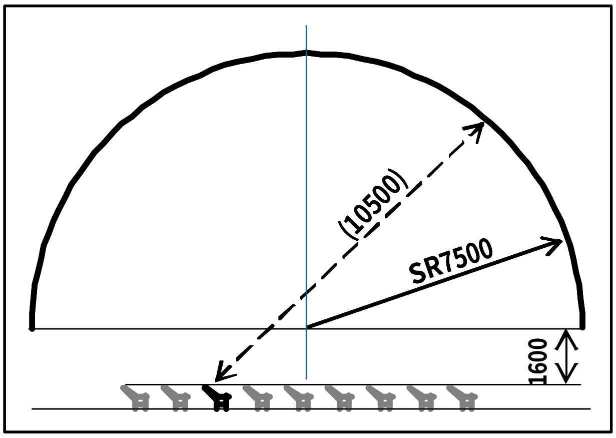

Fig.1. viewing angle in the dome

3. Optics and contrast

The authors set the projection angle of the fisheye lens 160 degrees. The value is designed for medium size dome. The projector will be set at the center and 1.34m lower side from the dome edge of the 15m dome where

15/2 x tan(180-160)/2)=1.34 .

This well balanced design with compact body will make the set up easy without extra construction for usual domes. No occlusion or no beams from the projector disturbs the audience.

Distortion, spherical aberration and chromatic aberration of the fisheye lens are well corrected using anomalous dispersion glass with multi coating.

Conventional projectors that has good contrast ratio were not enough for presentation of stars on jet black back ground because the ratio were dynamic value which is assisted by control of lamp luminance depending on scenes. JVC DLA-SH4K that is chosen for SMGII has the contrast ratio of 10000:1 in native and the pixel size of 3840x2400 [2].

The higher is the better for contrast, but there is no report on necessary and sufficient condition of the contrast ratio for planetarium. Effective contrast ratio for audience of the dome theater is different from conventional movie theaters. It is proportional to the contrast of projectors to the 3/2th power or square because the brightness of the background increases by the multiple reflections on the dome screen and the floor.

The practical contrast of SMGII in the dome seems better than the ratio of former model comparing the projector’s contrast.

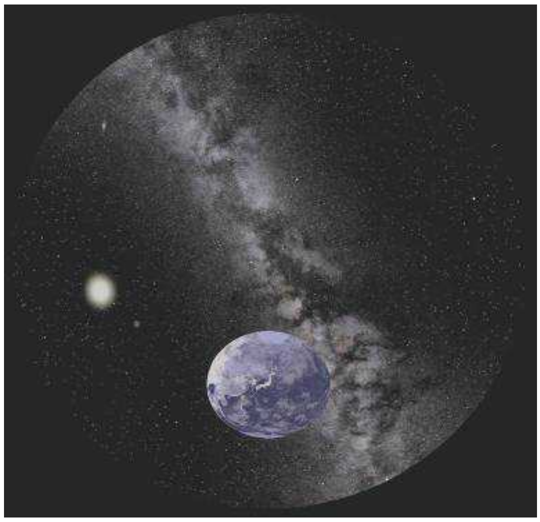

Fig.2. Conventional image

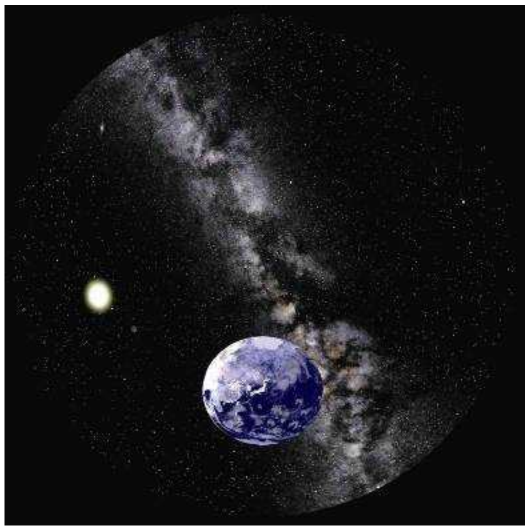

Fig.3. Improved image by SMG-II

4. Control system and software

One important issue is how to synchronize the image and the choice of graphic boards. The authors found that one PC with one NVIDIA Quadro

FX graphic board can display two 1920x2400 images at the refresh rate of 60Hz after checking many combinations of PCs and graphic boards.

This one PC system has great advantages. It needs no slicing process, no synchronize data traffic, can import movies or graphics directly and so on. Especially captured circular image by a fish eye lens is simply projected to the dome without compensation of distortion. That makes real time relay possible and decrease troubles of unexpected freezing.

Fig.4. Fish eye lens

Fig.5. SMG-II

Succeeding the popular easy-to-use interface of MEDIAGLOBE series, new graphical user interface is designed to allow easy customization of more complex show program just by loading the materials from the graphical user interface. It also has function that enables to graphically specify the display position as well as other various functions including cue, transparency, and fading. Digital slide function is also enhanced to allow demonstration of various visual effects such as wipe-in and rotation.

The “Show Director”, which was well-received in MEDIAGLOBE II, is a function to help operator to create “macro buttons” or “auto show” easily by storing the manual operations. “Dome Board” is a tool for drawing arrow, lines or letters anywhere on the dome. Operators can enhance their presentations by using allow or circle to show the position of particular celestial bodies or by drawing a message to the audience. In addition to playing real-time programs, this function can automatically play the programs stored with our Show Director function.

5. Contents

SMG II is equipped with all 88 constellations figures & lines, coordinate lines and more than 100 images of celestial bodies. All these images can be easily projected using the GUI.

In addition to showing stars down to 12.4 magnitude, 3D data of 118,000 fixed stars, and proper motion data of fixed stars at any time from 500,000BC to 500,000 AD, it utilizes the comprehensive stellar database “Mitaka” [3]. Powerful real-time simulations take audiences through the solar system and beyond, flying through 3-D space and time to the 13.7 billion light-year limit of the known universe.

6. Conclusion

The world first 2.4K full dome LCOS projector with one fish eye lens has developed. The contrast is 10000:1. It is capable of not just projecting images but projecting stars sufficiently on medium-size dome. The SMG II will be installed at Wakayama University this month and be used for super high resolution live broadcasting of the total solar eclipse with culture in Amami-Oshima Japan on July 22nd 2009.

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Auto Geometry for Synchronization between MEGASTAR Planetarium optical projector and Digital Planetarium

Takayuki OHIRA*1

This paper provides a brief description of the auto geometry technique developed in Ohira Tech Ltd. to automatically calculate the calibration between digital projectors and optical projectors in hybrid planetarium solutions.

1. Introduction

In recent planetarium industry world where neither optical planetarium projectors can answer the demands of complicated space simulations nor digital projectors can reproduce full realistic night sky on a dome, hybrid systems with the both become to be the solution.

MEGASTAR planetarium projectors of Ohira Tech are designed in a way to make the synchronization process between the two types easier via an auto geometry technology developed in Ohira Tech.

2. MEGASTAR models

MEGASTAR are the optical planetarium projectors series produced in Ohira Tech Ltd. MEGASTAR planetarium projectors were demonstrated during various occasions and events including IPS, EXPO, etc. and the beauty and reality of MEGASTAR sky was always highly appreciated.

3. Hybrid Systems

In recent years where the digital projectors enables virtual space travel and simulation of numerous of astronomical phenomenon, planetarium systems of hybrid solutions (Optical projector + Digital Projector) came into existence. A hybrid solution provides the advantages of both Digital and optical projectors into one planetarium show.

However, the problem of synchronization between these two systems which are completely independent is one of the main problems to face the planetarium industry in hybrid solutions.

4. Calibration

When the night star is projected via the optical projector, digital projectors can project constellation lines, figures, demonstrate various motions in solar system. As the two systems use same space domain which is the dome screen, they have to be synchronized to ensure that objects projected via digital projectors are located in their proper place in the optical sky.

Difficulties in synchronization usually is related to factors that the devices cannot be put in the center of the dome together, and that any dome surface always suffers distortion which results in positioning shifting when it is not properly considered.

The distance between a point or a star projected optically and this same point or star projected digitally for the same dome is called calibration. Measuring the calibration of various points across

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the dome screen is usually a tough and time consuming process which had to be undertaken before the two projectors can work together synchronically. Usually a higher quality requires larger number of points and calibration measuring.

If any of the projectors is shifted, the operation has to be repeated again. Optical and Digital projectors are usually strongly fixed to avoid such accidents.

5. Auto Geometry

MEGASTAR optical planetarium star ball projectors are designed to be part of a hybrid system and function with Digital projectors synchronically. To ease the process of calibration, Ohira Tech had developed a feature called Auto Geometry which is embedded in all recent models of MEGASTAR (MEGASTAR IIA, MEGASTAR IIB and some other models).

Auto Geometry feature automates the calibration process into what is known as auto calibration.

MEGASTAR Auto Geometry enabled star balls contains a laser beam source and a CCD camera and a control software accessing the digital projectors as well.

MEGASTAR star ball emits a thin laser beam for every point where calibration has to be measured. The digital projector also emits a bright line moving toward the laser beam position. The CCD camera fixed on the star ball recognizes the light emitted by the digital projectors and thus the calibration on this point can be automatically calculated. The star ball also automatically goes to next location and the whole process can be automatically done. See Fig. 1.

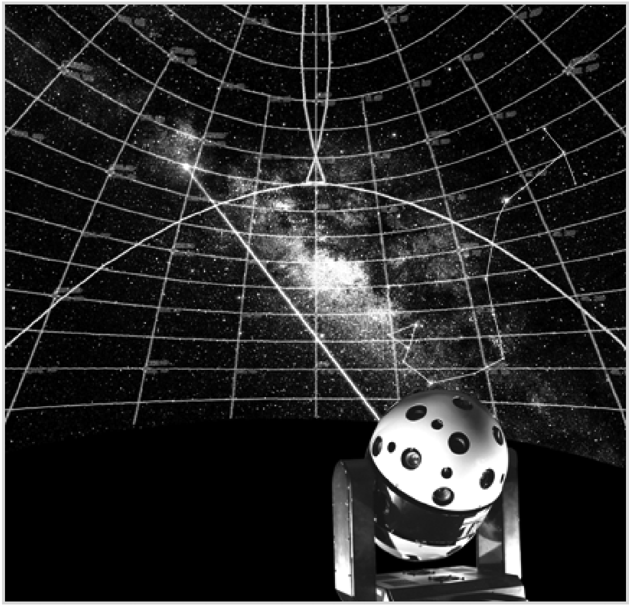

Figure 1: Auto Geometry

6. Conclusions

The Auto geometry technology automats the calibration process between the digital projector and optical projectors when a hybrid system is installed. Such an application makes a hybrid system possible to implement even in inflatable domes where quick installation has to be performed and no warranty that none of the devices could be accidently misplaced from its original location.

7. Further Study

Although auto geometry technique suggested makes the calibration process much easier, it is still an independent process. Dynamic calibration technology could be the next step toward full automation of the calibration process which is especially useful in instable inflatable domes where air pressure affects the shape of the dome.

Introduction of Activity for Consortium of 3D Image Business Promotion and a Member's Case Study of Development

Kazuya SAWADA[*1] and Toyohiko HATADA[*2]

Consortium of 3D Image Business Promotion is a private organization established aiming to contribute to the industrialization of technologies related to stereoscopic images in May, 2003. To offer business opportunities to the participation members, incubation activities of 3D business such as symposiums, research meetings for marketing research, and an exposition (an exhibition and technological seminars) are promoted. Here, we introduce these activities of the consortium. In addition, a case study of a development by one of the corporate members in the consortium is described.

1. Introduction

In this paper, we introduce activities in Consortium of 3D Image Business Promotion (the nickname is 'Rittaikyo' in Japanese), and a member's case study of a development which was caused because of an activity of 'Rittaikyo'. The case study is a development of 3-dimensional dome-shaped display system for stereoscopic endoscope by Panasonic Electric Works Co. Ltd, one of the corporate members of 'Rittaikyo'.

2. Introduction of 'Rittaikyo' [1]

2.1 What is 'Rittaikyo'?

'Rittaikyo' was established in May, 2003, by several persons involved in 3D technologies. The key person is Dr. Toshio Honda (the founder chairman of 'Rittaikyo', and now the professor emeritus of Chiba University).

The objectives of establishment were as follows;

- To clarify the vision of whole 3D image industry,
- To incubate promising business partners,
- To provide business opportunities to the members for related 3D image business,
- To contribute the industrialization for technical expressions of 3D Image.

The main purpose is to offer opportunities to find business promotions. Under this purpose, 'Rittaikyo' is promoting some following activities;

- To exchange among members & users,
- To exchange among members & content creators,
- PR activity, for example,
  - To distribute event informations from related organizers,
  - To exchange members' informations (corporate overview, new products, etc.) each other by the mailing list,
  - To deliver informations for 3D business.
- 3D Expo (Exhibition),
  - To provide broad business chances for not only members but also non-members,
  - To lead new business collaborations between exhibitors,
  - To hold a 3D theater, a sale, a salon and seminars as unique events.
- Symposium,
  - To provide and extend business opportunities (not only seminars, but also a concurrent exhibition and a banquet are organized for exchange of each other).
- Evening Salon (Research Meeting for Marketing Research),
  - To provide business chances under the specific theme (non-members introduced by members are welcomed to join).
- Working Group (WG),
  - To make plans and organize activities under requested themes by members.

2.2 Actual activities in 2008

The concrete contents of 'Rittaikyo' activities in 2008 fiscal year are described about the symposium, 3D Expo, and the evening salon.

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1) Symposium

A symposium entitled 'The railroad and virtual railroad simulator'was held on November 11, 2008 in the Railway Museum in Omiya, Japan that was rented all day long. The co-sponsor was the Virtual Reality Society of Japan. About 100 participants joined this symposium. The contents are the following two lectures and one panel discussion (Fig.1);

- Simulator & VR, Michitaka Hirose, Prof. of the University of Tokyo,
- Development of D51 Simulator, Minoru Mukaiya, Representative Director of Ongakukan,
- Panel Discussion: Key Point of the Railroad Simulator, by Hirose & Mukaiya.

The visit tour in the museum was also held. Especially, the participants got excited to the test ride of the D51 simulator. (Fig.2).

Fig.1. Scenery of the symposium

Fig.2. Test ride scenery of the D-51 simulator

As for the 2nd symposium in the current fiscal year, it will be scheduled to hold in Tokyo on April 14th. (The fiscal year of 'Rittaikyo' is up to the end of April.)

2) 3D Expo (Exhibition)

The 3D Expo (Fig.3) was held from December 3 to the 5th in Pacifico Yokohama, Japan. Concurrent exhibitions were International Technical Exhibition on Image Technology & Equipment and Advanced Photonics Technology Exhibition.

In the number of exhibitors, the member and the nonmember were 7 and 14 respectively. A 3D theater, a salon and seminars were done as special events with the exhibition.

In the 3D theater, a variety of 3D contents were demonstrated on the big 200 inch screen (Fig.4).

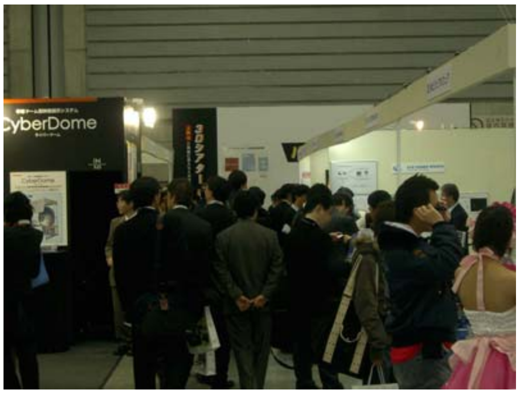

Fig.3. Scenery of the 3D Expo

Fig.4. Watching scenery in the 3D theater

The salon was a place of business meeting among exhibitors and participants, and the drink was offered free of charge.

The seminars were held by the following six themes;

- Applied 3D Image; Universe with 3D Effect, Takaaki Takeda, Researcher of National Astronomical Observatory of Japan,
- 3D Image Business; New Medical Field by 3D Image Technology, Hiroshi Oyama, Prof. of the University of Tokyo,
- A Guide to 3D Image; Mechanism from Brain Science, Masato Taira, Prof. of Nihon University,

- A Guide to 3D Image; Mechanism of 3D Image and Application, Tetsuri Inoue, Prof. of Kanagawa Institute of Technology,
- 3D Image Business; Meta-verse from the View of Venture Capital, Tsuyoshi Ogawa, Director of Itochu Technology Ventures, Inc.,
- The Day, When TV and Movie will be 3D, Yoshiaki Toda, Manager of IKSPIARI Co. Ltd. and Takashi Kawai, Prof. of Waseda University.

Especially, the last theme as a special seminar was held in a movie theater that was rented all day long near the exhibition space. This successful seminar attracted 524 participants.

As for the 3D Expo in 2009 fiscal year, it will be scheduled to be held from December 2 to the 4th in Pacifico Yokohama, Japan.

3) Evening Salon

Evening salons were held by six times in current fiscal year. Each theme, number of speakers and participants are as follows;

- Jun. 17th; 'The Day, When TV will be 3D' with 6 speakers, 10 members and 120 nonmembers,
- Jun. 26th; 'Evening Salon in the IVR Exhibition' with 10 members,
- Aug. 27th; 'Fusion of Art and Science' with 1 speaker and 22 members.
- Oct. 30th; 'Medical and Biological Engineering & 3D' with 4 speakers, 13 members and 17 nonmembers,
- Dec. 4th; 'Evening Salon in 3D Expo2008' with 15 members and 35 nonmembers,
- Mar. 12th; 'Evening Salon in Knowledge Capital Trial 2009' with 6 members and 3 nonmembers.

3. Meber's Case Study of Development

Panasonic Electric Works Co. Ltd (PEW), one of the corporate members of 'Rittaikyo' started some new attempts after participating in 'Rttaikyo'. Among these attempts, this chapter introduces a development of 3-dimensional dome-shaped display system for stereoscopic endoscope.

3.1 Outline to start of the development

PEW already has developed a dome shaped 3D VR display system, CyberDome, before participating in 'Rttaikyo'. In the series of CyberDome, there are various sizes from an open caliber 1.4m to 8.5m. Fig.5 shows CyberDome8500 (8.5m in diameter) that was set up in PEW's Tokyo headquarters in April, 2003. Some of CyberDome series have been exhibited to exhibitions such as 3D Expo several times so far. As an example, the appearance of CyberDome3700 (3.7m in diameter) exhibited to 3D Expo 2006 is shown in Fig.6.

Fig.5. CyberDome8500 in PEW's Tokyo headquarters

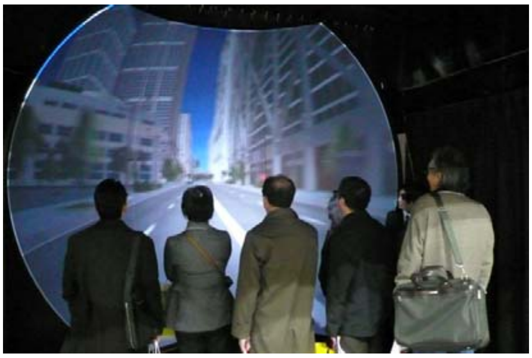

Fig.6. CyberDome3700 in the 3D Expo 2006

In an exhibition, Prof. Hashizume's laboratory members found our CyberDome. Prof. Hashizume, Faculty of Medical Sciences, Kyusyu University, is one of the world authorities in laparoscopic procedures. As the result, CyberDome1800 (1.8m in diameter) was adopted in his laboratory as a simulator usage.

After that, we started the joint research development of a special system for laparoscopic procedures based on the CyberDome technology.

3.2 Development of 3-dimensional dome-shaped display system for stereoscopic endoscope

Our joint research development with Prof. Hashizume was being supported by NEDO (New Energy and Industrial Technology Development Organization), one of the affiliated organizations of METI (Ministry of Economy, Trade and Industry), Japan. The background of the development is as follows;

- Despite current advances with technology, laparoscopic surgeons still need a long experience to overcome the lack of depth perception on a 2-dimensional (2D) display,
- Although 3-dimensional (3D) display provides depth perception, 3D systems have not been widely used in laparoscopic surgery, possibly due to the side effect or poor quality in 3D images.

The total appearance and an usage condition of our developing 3D dome-shaped (3DD) system are shown in Fig.7 and Fig.8 respectively.

Fig.9 shows the specifications of the dome-shaped screen. The screen is a shape to cut a ball of 1,000mm in diameter, and the open caliber is 600mm. This intends that all points on the screen are equivalent distances from an operator's standard viewpoint.

Fig.7. Total appearance of the 3DD system

Fig.8. Use scenery of the 3DD system

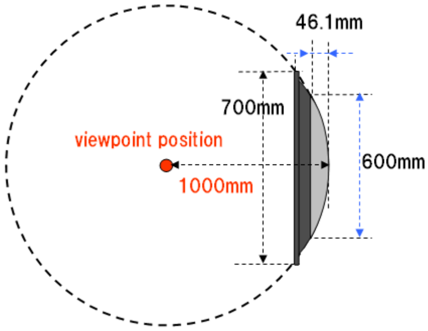

Fig.9 Specifications of the screen

3.3 Outline of evaluation experiment results

In the present study, 23 students of Kyushu University volunteered for the system's evaluation. We provided several tasks on depth perception and laparoscopic procedures, in order to evaluate the effect of 3DD system compared with 2D system and a conventional 3D system with a flat display. The tasks are cognition-tasks, motor-tasks and a conventional suturing & knot tying task. The execution time, the errors, and the flight path of forceps were analyzed. The results were as follows;

- In all cognition tasks, the 3DD system significantly improved depth perception,
- In suturing & knot tying task, the 3DD system significantly shortened the execution time and reduced the number of errors,
- Even novices were able to move the tip of forceps widely when using the 3DD System,
- Regarding fatigue, there were no significant differences,
- The result of the flicker test which measured eyestrain showed that 3DD system was not tiring than 2D system.

These results suggest that our novel 3DD system will be able to contribute to safety of laparoscopic surgery [2][3]. The 3DD system will be able to be put on the market in near future.

4. Conclusion

In this paper, we introduced activities for Consortium of 3-D Image Business Promotion (the nickname is 'Rittaikyo' in Japanese) and a case study of Panasonic Electric Works Co. Ltd, one of the corporate members of 'Rittaikyo'. The case study was the development of 3-dimensional dome-shaped display system for stereoscopic endoscope which was caused because of an activity of 'Rittaikyo'.

This development project became one of the chances, and we were able to hold a 'Rittaikyo' symposium entitled 'Medical Care and Three-Dimensional Vision' on Jan. 16, 2008 in Shibuya, Tokyo. Four medical doctors lectured including Prof. Hashizume who is the co investigator of the above-mentioned development project. In the symposium, an exhibition was held, and several systems related to some medical treatments including the above-mentioned 3DD system were exhibited.

Table 1 shows the member composition of 'Rittaikyo' on Feb. 27, 2009. Six years passed after 'Rittaikyo' had been established. In 2009 fiscal year, we will newly plan to found an individual member (associate member) qualification which includes content creators. Moreover, we are scheduling visit tours and workshops as new activities in place of symposiums. 'Rittaikyo' will plan to advance the activities while updating the contents in the future.

Table 1 Member composition of the 'Rittaikyo'.

Corporate	29
Teacher	17
Creator	3
Support Group	7
Adviser	2

on February 27, 2009

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SKY-SKAN UPDATE – PROJECTS, PRODUCTS AND THE FUTURE

Steven T. SAVAGE*

1. Introduction

It's always fantastic to be here in Japan. My days are filled with great adventure and good beer in the evenings. It's great to see many of you, even some of my Western colleagues who I rarely get to see. It's been great having the chance to spend some time with you.

I hate PowerPoint. I feel very uncomfortable in front of a flat screen! I want the dome over me, so I will try to make it quick, and again. I don't want to talk a lot about technical things; I just want to give you a quick overview of the things that are happening in the Sky-Skan universe – some new cutting edge projects that we've been working on, Sky-Skan in the News and some scientific visualizations which are particularly interesting.

2. New Cutting-Edge Projects

Last year in the summer, we built the world's very first 8K x 8K planetarium system in Beijing. It opened just before the Summer Olympics and it delivers the sharpest image in the world. It is used in concert with the Zeiss Mark IX, and makes a very beautiful, sharp, bright picture.

Fig. 1 Beijing Planetarium; Sky-Skan definiti 8K x 8K system projecting 8K image of Chinese National Observatory

We filmed a number of 8K images as we toured around China to capture Chinese icons in 8K. This is of the Chinese National Observatory (fig. 1).

We also integrated DigitalSky with the Zeiss Mark IX (fig. 2).

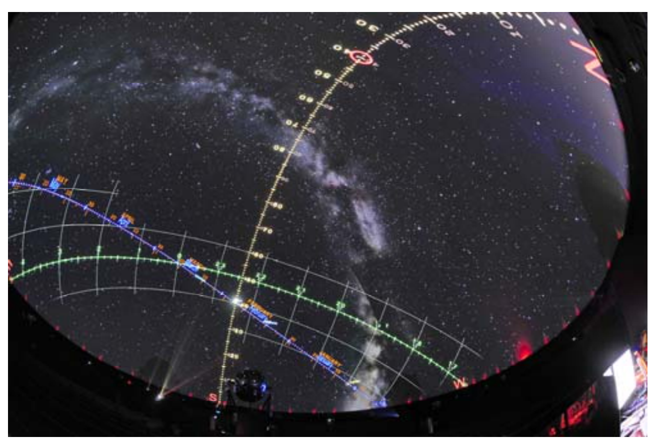

Fig. 2 Image showing the DigitalSky grids and Zeiss Mark IX grids overlapped as the two systems track through the night sky.

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The next project is also an 8K theater, but this time it is also in stereo (fig. 3). This is being built for the new Macao Science Center, which is about an hour by boat from Hong Kong.

Fig. 3 Shot of the new Macao Science Center under construction.

This is an amazing facility. It will have the brightest picture in the world: 132,000 lumens - in stereo. This level of light is particularly good for stereo because about 70% of the light is lost within the filter technology. It will deliver an experience nearly equivalent to the 4K-2D experience, but in stereo.

The next project is new theater upgrade in Hong Kong (fig. 4). This magnificent city supports a very beautiful dome at the Hong Kong Space Museum and it will have an 8K mono system that is convertible to 4K stereo. This will be coming in 2009.

Fig. 4 Hong Kong – from Victoria Peak.

3. Sky-Skan in the News

Sky-Skan was recently featured in a segment of the, "New Hampshire Chronicle" on WMUR television. The segment can be viewed on our website at www.skyskan.com.

4. Scientific Visualizations

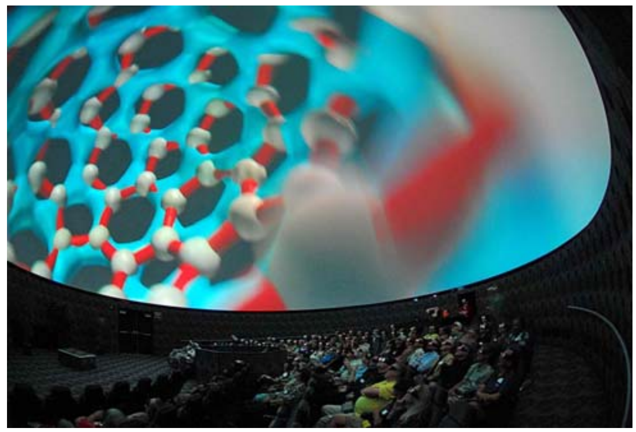

Fig. 5 Photo of Bucky Ball visualization – 5th order carbon, shown in 3D stereo at 'Imiloa Astronomy Center.

To summarize this next section of Sci Viz -- I have three 3 animations that I will discuss:

The first is a DNA sequence that was done by Drew Berry in Melbourne and it's a fantastic animation on DNA replication. It's the most incredible animation I've ever seen. It's a scientific visualization but it's done in a way that shows, in a clear way, what a thousand words could not describe.

The second is a real time aurora generated from DigitalSky and, of course, was inspired by Carter Emmart from AMNH, as a lot of our work has been. Carter has been such an incredible pioneer and very inspirational.

The third is a weather tool called "FlowViz" – it provides the capability of doing real time visualization using data from orbiting weather satellites.

DNA Sequencing and Proteins:
We begin with our first Sci Viz of DNA replication (fig. 6). It is a relatively short animation so I've repeated it three times. You will see there are DNA strands coming and going. The animation shows the DNA strand coming into a protein and you can see it's being split – this is shown in real speed – it's a very quick chemical process. Notice the hydrogen bond between the two sugar phosphate ladders is being snapped into two individual strands. Then the two proteins make their compliment and reproduce two new DNA strands – exactly replicated very fast – it's quite a good example of a nanomachine!

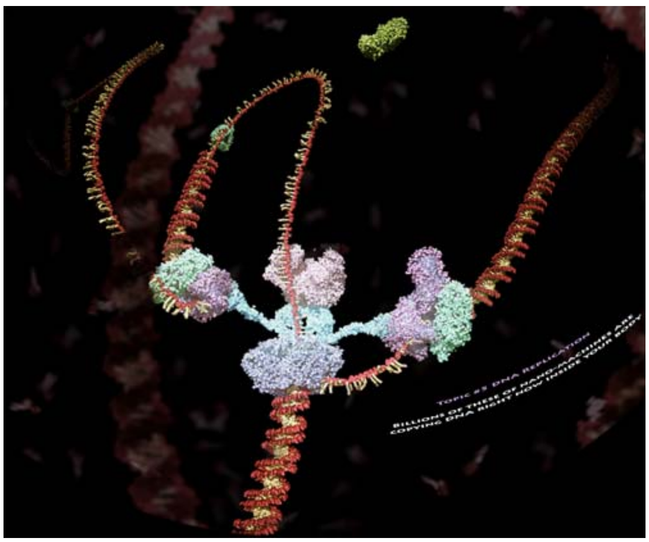

Fig. 6 DAN replication.

What's interesting about this, depending on your point of view, is you could say, "Wow, this is a fantastic simulation of how the body reproduces DNA."

So, it's a fascinating world – you can see proteins coming and going, knowing where they are to attach (fig. 7). There are, in fact, little atomic keys that stick out so proteins can't click into the wrong place. It begins a very fascinating conversation. And, in fact, I think some of these very important images are just as much fun and just as challenging to teach as astronomy.

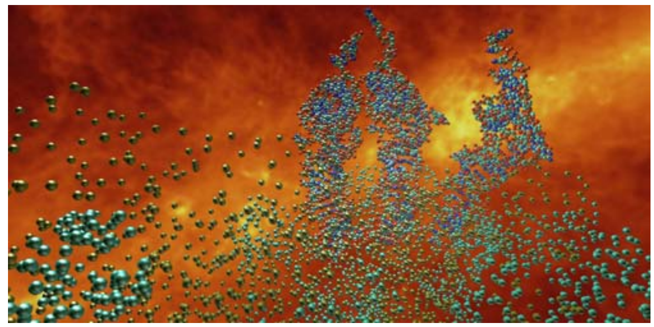

Fig.7 Protien visualized in DigitalSky, courtesy Telus World of Science Edmonton, Canada

Real Time Aurora:
The second clip is of a real time shader of the Northern and Southern Aurora Borealis that we've built for DigitalSky 2 (fig 8). It is a very interesting shader because it allows us to control the amount of energy from a CME (coronal mass ejection) and we can add minimum and maximum sizes from the aurora, which is a nice feature.

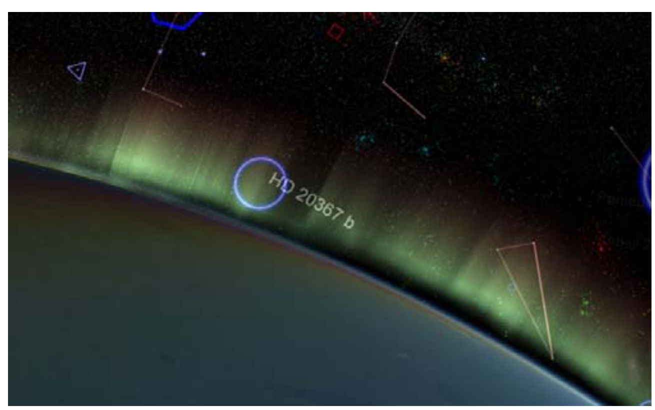

Fig. 8 Northern Auroa Boralis rendered in real-time by DigitalSky 2.

Flo-Viz Weather Vizualization:
The sci viz is FlowViz. This is data shows about three days of Global weather in real time, in this case, wind data at three altitudes (fig 9).

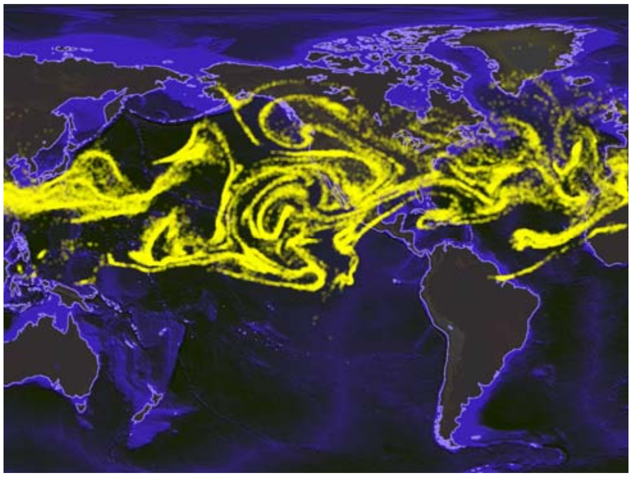

Fig. 9 Flow-Viz data of Earth's Air currents rendered in DigitalSky.

We dropped a dyepot on Tokyo and you can see the winds (these are upper winds) carrying the dye paticles all the way across the Pacific (fig 10). In fact, over a period of time, you will see the same weather pattern circumnavigate the Earth and comes back, almost to Tokyo again.

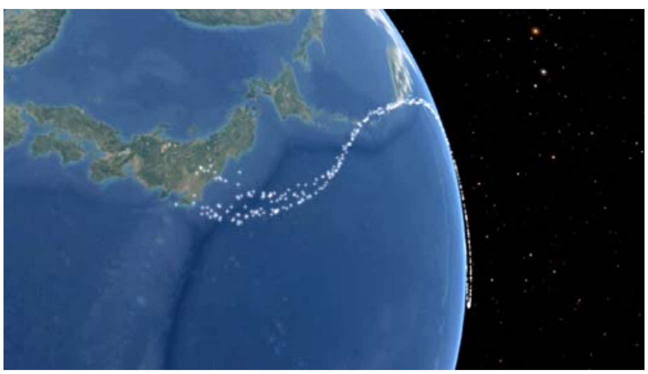

Fig. 10 Dyepot on Tokyo.

We've dropped another dyepot on Madagascar. Madagascar is a very interesting area because nearby, the warm Indian Ocean and the cold Antarctic seas join as a constant vortex - which is almost like Earth's version of a red spot, like Jupiter's. It is not red in color but energized but the ocean's temperatures. This region is special as the ocean and wind currents are worth watching for changes in this indicative zone of climate. Changes in the size, shape and placement of this zone may indicate changes in our climate.

Fig. 11 Dyepot on Madagascar.

5. Conclusion

I hope these data visualizations will inspire children to choose the sciences for their field of study. Maybe one of these children will discover the origin of the universe!!

Fig. 12 Three excited children!! 'Imiloa Astronomy Center, Hilo, Hawai'i

Quadratura, the future of real-time dome system

Toshiyuki Takahei[*1]

For digital planetarium theaters and immersive environments, I developed a brand new software called Quadratura. Technically it's a real-time PowerPoint-like presentation tool for immersive environments. It is the most intuitive way to utilize immersive environments such as domes, multi-projection and stereoscopic theaters. Real-time composition of various types of media opens many doors of possibilities in what you can do in such an environment. Furthermore, with its extensibility, it can be a platform to implement real-time scientific simulation and visualization. For content creators, it can be a new way of content creation and distribution. Change your mind and prepare for this new era.

1. Background

In the summer of 2008, we built the first public stereoscopic dome theatre in Japan, at the Science Museum, in Tokyo. We named it the 'Synra Dome', where 'Synra (Shinra)' means 'everything in the universe' in Japanese. This new dome theatre will be used not only to show astronomical content, but also content from various other fields of science, arts, entertainment, and more with its immersive and interactive capabilities. For this dome theater I developed a brand new presentation software for interactive live shows and content designing. In this paper I'll describe this new software 'Quadratura' that enhances the capabilities of this new full-dome environment. (see [1]).

2. Concept and Purpose

I designed Quadratura as a real-time presentation tool for immersive theater which means not only domes or stereoscopic domes, but also any shape of screen with single or multiple projector clusters. We needed an intuitive way to utilize a complicated display environment as easily as Power Point, not like professional 3DCG packages. Based on the current improvements of computer graphics technologies, most of the composition and slicing functions are available in real-time speed. Thus, this tool is also a dramatically fast content designing tool. In most cases we no longer need to perform lengthy renders of dome masters. Full-dome content consists of source images, movies and text materials with a small script file, so it'll be easy to test, modify and also distribute to others. It also could be a software platform of such immersive theaters, so I made it extensible enough to display not only presentation materials but also unique content modules (ex. In Synra Dome we put a real-time galaxy collision simulator in it). It can manage all PCs, Projectors, light and audio control, so it also could be an integrated theater control system. This is the software that we needed in our Synra Dome.

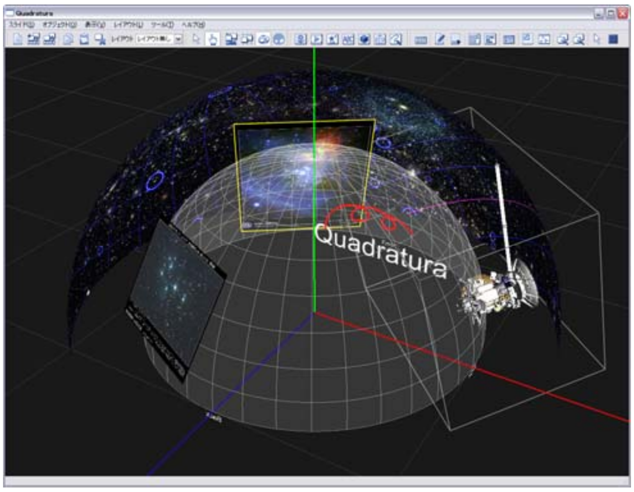

Fig.1. Quadratura composites various media in real-time.

3. Screen Surface Coordinates

In usual implementation, objects are placed in an orthogonal coordinate system, so their spatial positions are represented as x, y and z values. But for presentation use, most objects such as images, movies and text should be facing the audience. So in Quadratura, I adopt a 'screen surface + depth coordinates system' to represent objects' positions. It allows intuitive drag and drop object placement like

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in PowerPoint. Better still, with this coordinate system one can use the same content both on flat screens and dome screens by simply changing the base coordinate system according to the new screen shape. (see [2]). All objects are actually placed in 3D space, so it supports stereoscopic rendering too.

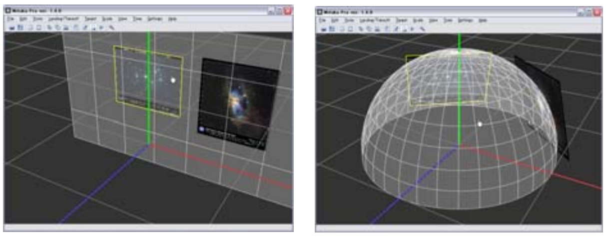

Fig.2. Flat and Dome screen projections.

4. View Styles

During interactive presentations, the speaker will be able to put additional objects at any time and place he or she wants. To get the most out of the immersive environment, the speaker should check the entire view of the presentation space and be able to layout the objects in this view.

In Quadratura, changing the view style of the operation console can be done at anytime. It has 3 view styles: First Person View [3], 3rd Person View [4] and Dome Master View [5]. With these views, one can quickly grasp the entire layout of objects and arrange them intuitively.

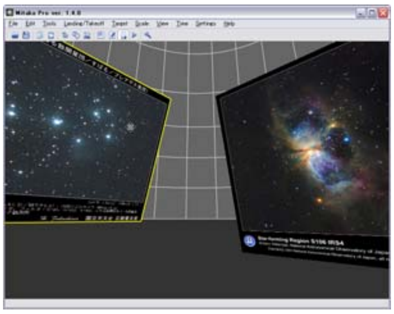

Fig.3. First Person View.

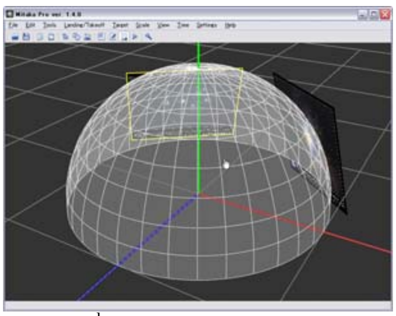

Fig.4. 3rd Person View.

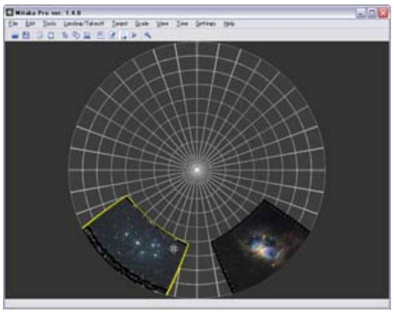

Fig.5. Dome Master View.

5. Object Types

In Quadratura, you can add objects just by dragging and dropping the files from the explorer windows onto the 3D screen surface in the console window. (see [6]).

Currently supported object types are: Images (with alpha, most common formats and sequential images), Movies (with alpha, most common formats), FITS files (real-time exposure processing supported), 3D models, Texts and All-sky Images / Movies (with alpha, Dome Master, Panorama and Cubic Files format supported), Web pages and Remote Desktop surfaces. All these types of objects can be placed and composited in 3D space. This makes the tool useful, not only for interactive presentation, but also for the pre-visualization of full-dome movie content. I found that composition of all-sky movies with alpha channel allows for powerful full-dome special effects.

Furthermore, Quadratura SDK can extend these supported object types easily. Currently, I have plans to develop some additional object types such as: Real-time particles, Live video chat and 3D avatar characters.

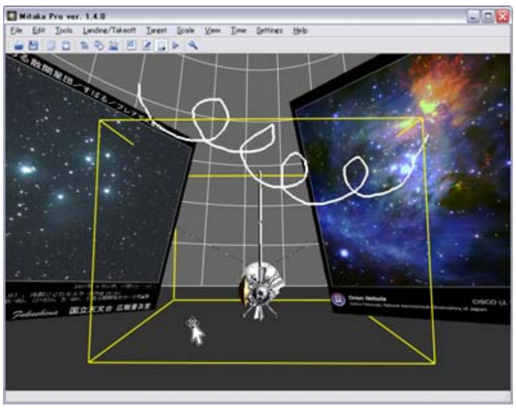

Fig.6. Images, 3D Model and Free Drawing

6. Presentation Assistance

Once the objects are placed around the presentation space, you can store the current objects and layout as a 'Slide'. Notice that in this tool, a slide does not mean a 2D image but a whole 3D scene environment. An entire presentation can be done by showing slides sequentially. For accessing a specific slide, you can select the slide from the console window or directly from the on-screen slide launcher.

To assist the presentation, Quadratura also has various transition effects for each object (implemented by a shader language and extendable by the user). Virtual 3D cursors and free drawing pens are quite useful for marking up the important points. These cursors and pens can move across the entire area of the screen surface projected by different PCs.

7. Timeline motion control

For content creation, Quadratura has a useful timeline based animation designing tool. (see [7]). It looks like Adobe Flash, Director and any other non-linear editing tools and 3DCG packages, so most content creators will be familiar with this tool. All types of objects, position, rotation, scale, visibilities and other properties can be controlled by key frames, external devices, or scripts.

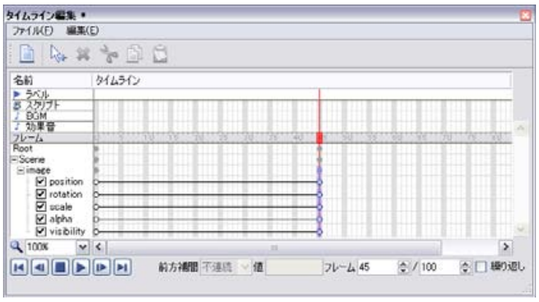

Fig.7. Timeline Editor dialog box.

8. Script Control

All operations in Quadratura are implemented as internal script commands. So you can record your interactive presentation into a script file, and replay it later. This replay capability allows the rendering of the entire presentation as a Dome Master movie. You can also make useful macros for your presentations.

9. Projection Correction

If you have an optical planetarium facility, you can project the Quadratura scene over the starry scene with as many projectors as you want. This tool comes with integrated real-time slicing functionalities (distortion correction [8] and edge blending), so you can fill the displayed area as large as you want. These projection corrections are designed not only for domes but for any screen shapes, so you can use this presentation tool for any kind of immersive theatre. With this real-time slicing functionality, you can drag and distort the displayed image directly. It is extremely useful for quick projector adjustments.

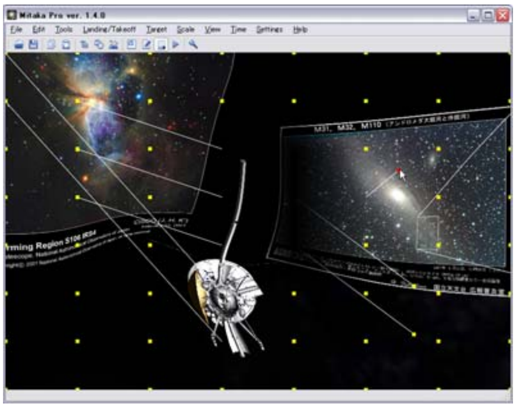

Fig.8. Direct distortion correction.

10. Embed in Applications

The last and most important feature of Quadratura is that it is also an embeddable 3D library for OpenGL-based real-time applications.

I integrated it in Mitaka Pro, a real-time space simulator which was originally developed by the 4D2U Project, to make it a full-featured astronomy presentation software. (see [9]). Quadratura works as an overlay plane of the space scene, and shares the projection correction and setup of the base application Mitaka Pro.

Integration of Quadratura with such interactive software greatly enhances its usability. In the next step I'll integrate Quadratura with Uniview, and try to work with other visualization software.

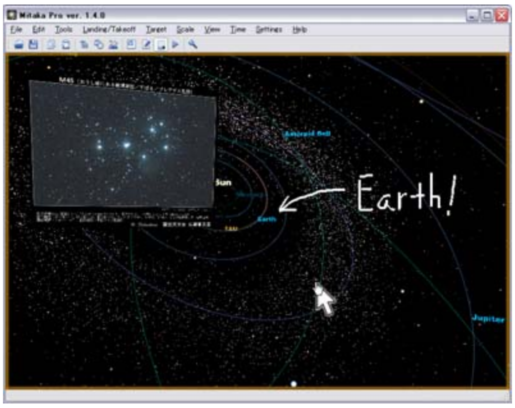

Fig.9. Quadratura working in Mitaka Pro.

11. Conclusion

For the Synra Stereoscopic Dome theatre, I have developed a unique interactive presentation tool Quadratura. I found that it makes dome environments much easier to use, and extends their capabilities. Soon I'll release this software as my product. I hope many people love this tool and seek new possibilities for dome and immersive environments.

References

[1] Toshiyuki Takahei, 2008, "Full dome presentation and content development tools", Proc. of the Full Dome Summit 2008 in Chicago.

[2] Synra Dome Web Site : http://www.synra.jp/

[3] Quadratura product page (in Japanese) :
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Author Index

Agata, H. 15, 59
Emmert, C. 55
Fukusato, K. 87
Fukushima, A. 101
Goodman, A. A. 9
Hatada, T. 107
Hayashi, M. 59
Hirai, A. 15
Hirohashi, M. 37, 41
Ichihashi, Y. 49
Iiyama, O. 33
Inami, H. 39
Ishimaki, N. 101
Ito, T. 49
Itoh, S. 15
Iuchi, M. 37
Iwashita, Y. 59
Kagaya, Y. 45
Kamiyama, H. 91
Kaneko, K. 93
Kato, T. 59
Kimura, K. 39
Klashed, S. 77
Kohsaka, H. 33
Koike, K. 39
Kokubo, E. 59
Kokubu, H. 25
Kurogane, H. 97
Laatsch, S. 67
Lantz, E. 73
Ohira, T. 105
Ohmura, K. 3
Ohta, N. 93
Oka, S. 39
Okuno, H. 59
Makino, J. 59
Masuda, N. 49
Matsuoka, H. 39
Miura, A. 25
Miura, H. 29, 59
Miyama, S. 59
Mochizuki, G. 25
Naito, S. 15
Nagai, T. 15
Nakayama, H. 15, 25, 49
Negishi, I. 97
Nishigaki, J. 101
Nukatani, S. 59
Sakamoto, S. 39
Savage, S. 19, 113
Sawada, K. 107
Shimo, M. 101
Tabe, I. 33, 39, 81
Takahei, T. 59, 63, 117
Takeda, T. 25, 59
Takeuchi, K. 101
Ueda, F. 101
Watanabe, Y. 37
Yano, T. 97
Yonezu, M. 37
Yoshikawa, M. 33

Proceedings of the International Symposium for Immersive Scientific Visualization