Super High Definition Three-Dimensional Display Environment Applied to Visual Data Mining

So SATO
System Design and Management Research Institute
Keio University
Yokohama, Japan
e-mail: sosato@2010.jukuin.keio.ac.jp

Yoshisuke TATEYAMA, Tetsuro OGI
Graduate School of System Design and Management
Keio University
Yokohama, Japan
e-mail: tateyama@sdm.keio.ac.jp, ogi@sdm.keio.ac.jp

***Abstract*— Recently, the quantity of accessible data continues increasing, and the importance of data mining is also increasing. On the other hand, highly developed computing facility enabled visual data mining in immersive environment. Visualization has an important role in current data mining, and the rapid progress on visualization devices, such as super high definition stereo display, can enhance the existing data mining scheme. Super high definition stereo displays can represent large amount of information to the users. But it does not mean that the information is conveyed correctly to the users. In this paper, we conducted experiments on human perception, and the results suggest human cognitive limitation is no longer ignorable in visual data mining. We developed visual data mining platform focusing on point cloud representation, and it was applied to visual data mining on seismic data.**

Keywords-component; 4K Stereo Image, Immersive Projection Display, Seismic Data, Cognitive Limitations

I. INTRODUCTION

Due to the increase of the amount of data treated in various fields, data mining [1] is becoming more and more important. Visualization has been so important in data mining that they are combined tightly into visual data mining. Many visualization methods [2] and display environments have been proposed for visual data mining. Especially, the usage of immersive environment is considered to be effective [3][4].

Generally, the early phase in data mining is repetitious process of trials and errors. Thus, the process of the visual data mining can be modeled as a human-computer interaction cycle as shown in Fig.1. In this model, visual information is transmitted from the computer to the human as indicated by bold arrow.

To enhance this cycle, it can be effective to increase the amount of visual stimuli conveyed from the computer to the human. From this point of view, it is expected that super high definition stereo display can be used effectively [5].

On the other hand, we also should consider the limitation of human's perception in recognizing the visual information, and this limitation cannot be ignored.

Though a lot of visualization techniques have been proposed for the visual data mining as mentioned above, we focused on the point cloud data representation, to fully exploit the super high definition stereo display environment.

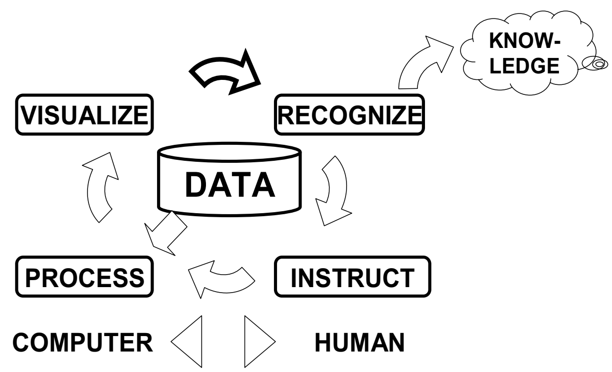

Figure 1. Visual Data Mining Scheme

To estimate the human limitation in data mining cycle, we conducted experiments on the human perception. Then, we developed visual data mining platform using point cloud representation to enhance the first phase of data mining. And we applied the platform to seismic data for validation.

II. ENVIRONMENTS AND SYSTEM CONFIGURATIONS

A. Hardware

In this study, the super high definition stereo display system was constructed as a visual data mining environment [6]. In this system, we adopted the passive stereo projection method using 180 inches rear projection screen (Nippura, Blue Ocean) and the stacked two 4K projectors (Sony, SRX-S110) with the polarizing filter. The user can see the high resolution stereo image by wearing the polarized 3D glasses. Because 1 pixel has approximately 1-mm width in this screen, the resolution is higher than the difference-sensitivity of the user with the eyesight of 1.0 (that means 1/60 degrees of angle-of-visibilities can be distinguished), when it is seen from the position 4m distant from the screen surface.

In order to render high definition stereo image, distributed configuration of the computers that consist of two renderer nodes (Dell Precision T7400, 2xQuad Core Xeon 3.2GHz, NVIDIA Quadro Plex 1000 Model IV) for each eye and one master node to control them is used.

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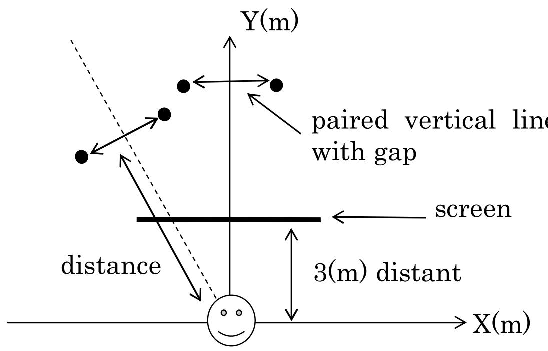

Figure 2. Configuration of Experiment on Two Lines Recognition

B. Software

As for the software, Open CABIN Library is used to execute the visual data mining program on the distributed computer system. Open CABIN Library is a software platform using plug-in mechanism [7]. Applications are constructed as a shared object format and they are executed from the prompt in the master process. Then, the programmers write programs as event handlers for each plug-in application.

Since Open CABIN Library conceals functions such as frustum calculation, device handling and communications between the nodes, ordinary OpenGL programmer can develop applications easily without considering the specific display environment.

III. EXPERIMENTS

Since the constructed super high definition stereo display can represent a large amount of visual information, it can be expected to be used effectively for visual data mining. Therefore, we conducted several experiments to quantify the performance of the super high definition display system including human's perception.

A. An experiment on two lines recognition

First, an experiment on two lines recognition was conducted. In this experiment, vertical two straight lines were displayed to the subject who stood at the position of 3m away from the screen as shown in Fig. 2. These straight lines have gap perpendicular to the view direction. The subjects could control the distance of lines from them by using the controller, and they were asked to report the maximum distance where they could distinguish each line from the other by pressing the button on the controller. The visual stimuli of two lines were displayed with various gaps and in various directions.

Fig.3 shows the results of the experiment for five subjects. In this graph, average distances for each direction and for each gap are plotted. If these results were considered as eyesight, the average angle of the recognized gap was 1.66 minutes and it was equivalent to about the eyesight of 0.6.

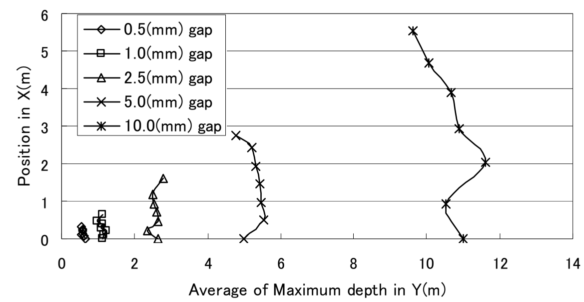

Figure 3. Result of Experiment on Two Lines Recognition

. This result was low relative to the recognizable angle of 1.15 minutes calculated from the pixel size mainly by the effect of the line widths. It implies that screen resolution still is the bottleneck, and further enhancement of the display can make the result better.

On the other hand, this graph shows that the subject could recognize 0.5mm gap between lines when they were displayed at the distance of about 0.5m. This gap was narrower than the pixel size, and we can see that this system has the ability of representing higher resolution image than the pixel size by utilizing the effect of stereo vision.

B. An experiment on depth sensation for point cloud data

The high resolution image displayed on the super high definition display can be used effectively to visualize a large amount of point cloud data. An experiment concerning the effective data visualization to utilize the advantage of the super-high definition display was conducted as shown in Fig. 4.

In this experiment, uniformly distributed point cloud was displayed to the subjects standing at the position 3m away from the screen. Points were distributed in a rectangular solid area and they were colored randomly.

144 kinds of visual stimuli of the point clouds were displayed, by changing the number of points (12 kinds, less than 500,000 points), distance to the near side (1, 2, 3m), and the depth of the data volume (1.0, 1.5, 2.0, 2.5m).

The subjects were asked to evaluate the sensation of depth felt from the displayed image using the three-grade system (2-clear depth, 1-unclear depth, 0-no depth).

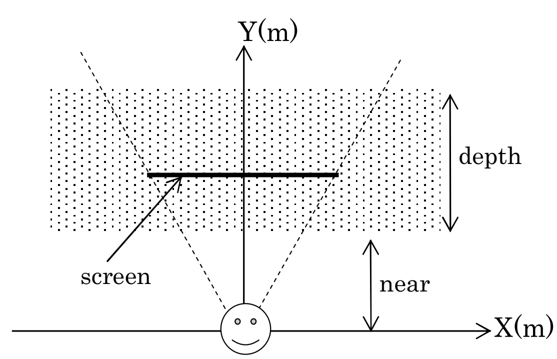

Figure 4. Experiment on Depth Sensation for Point Cloud Data

Fig.5 shows the result of this experiment for 9 subjects. Each plotted point means average value of the evaluation and they are grouped by the distance to the near side. From the result, the evaluation of the depth sensation felt by the subject decreased according to the increase of the number of the displayed points. Namely, we can see that the representation ability of the super-high definition display for the three-dimensional image would decrease when it displays too much data simultaneously though it can represent super high resolution image. And, it is also understood that this ability would decrease steeply when the distance to the near side is short.

C. An Experiment on detecting void in point cloud

When the visual data mining is actually performed for point cloud data, finding the feature of the distribution of the point data is very important. To measure the capability of detecting feature of the point cloud data using the super high definition display, the following experiment was conducted. In this experiment, the stimuli of the point cloud data with spherical void were displayed using the stereo image or the monaural image to the subject who stood at the position of 3m from the screen as shown in Fig. 6. The subjects were asked to report the existence and the position of void in the point cloud by pushing the button on the controller. The radius of the spherical void was 0.3m and it was located at the position of 1.0m or -1.0m on x-axis.

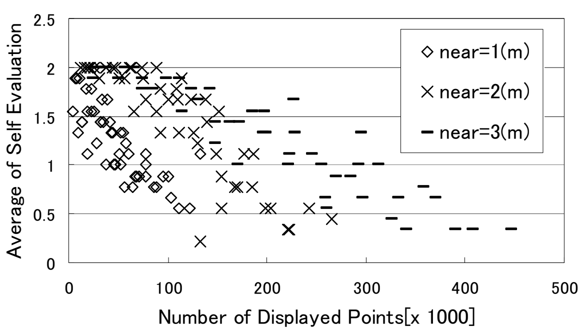

Figure 5. Result of Experiment on Depth Sensation for Point Cloud Data

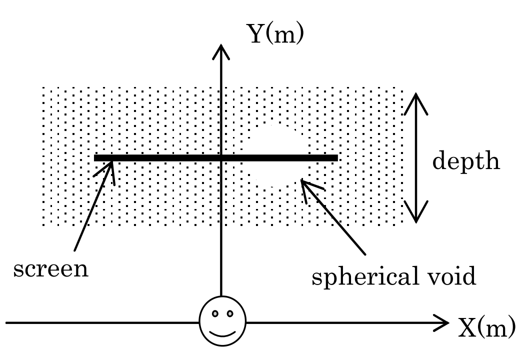

Figure 6. Configuration of Experiment on Detecting Void in Point Cloud

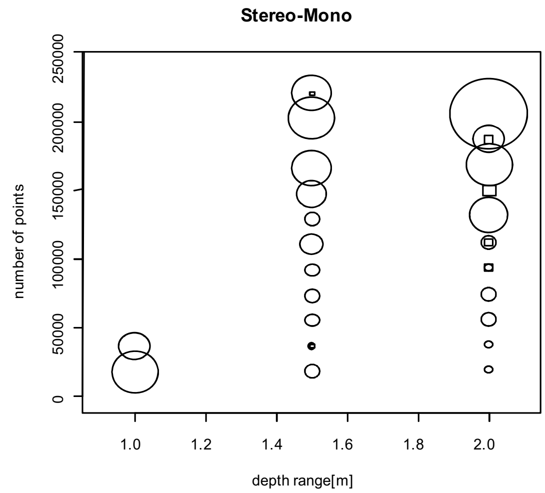

Figure 7. Result of Experiment on Detecting Void in Point Cloud

Fig. 7 shows the results for 9 subjects. In this graph, the differences in the correct answer rates between the results with stereo and the results without stereo for the same conditions are plotted. Large circles mean that the correct answer rate was higher when the stereo image was used, and large squares mean that the correct answer rate was higher when the monaural image was used. From the result, we can see that the stereo image could be used effectively to detect the void in the point cloud when the depth of the distributed data was large (depth = 1.5m, 2.0m), though there was no difference when the depth of the distributed data was small (depth = 1.0m). Therefore, it is expected that the super high definition stereo image can be used effectively to perform the visual data mining for the point cloud data.

IV. VISUAL DATA MINING PLATFORM

In general, an effective data visualization method in immersive environment is developed as a domain specific method. But it is difficult to realize effective visual data mining because the data mining is usually performed without the knowledge about the feature of data. So, we developed a platform of visual data mining using the super high definition stereo display environment to enhance the performance in the first phase of data mining.

In this platform, multi dimensional numeric data is visualized using the point cloud representation, since the super high definition display can be used effectively to represent the point cloud data.

A. Data Flow

To import domain specific data into the visual data mining platform, we adopt the table structure constructed in the RDBMS as an interface. This table consists of ID field and eight floating point number fields (val0, val1, … val7). As shown in Fig 8, the domain specific data is appropriately transformed to the abstract eight dimensional data and it is stored in the table. Thus, users can perform the data mining independently from the original domains of the data. When the visual data mining is performed, this abstract data is mapped to the parameters in the visualization. Displayed data has attributes such as the position of three-dimensional orthogonal coordinates (X, Y, Z), the color value (C), and the filtering reference value (R).

B. Features of Interface

In the data visualization using the immersive display environment, intuitive representation is weighed more than precise representation. But in the visual data mining, preciseness is very important.

Therefore, we adopted GUI interface and physical controller to realize intuitive operation with preciseness. Fig. 9 shows the snapshot of the GUI interface. This interface has the following features and functions.

1) Mapping Control

Five parameters (X, Y, Z, C, R) of the displayed data are represented as linear combination of the eight-dimensional abstract data, and the users can set the coefficients of this representation. Each tab in the right side corresponds to the parameter of the displayed data, and each slider can be used to control the coefficients.

2) Region Pointing

In this system, pointing function was implemented to specify the rectangular region in the visualized data. The center of the region and the widths along each axis can be changed using the sliders placed in left side.

3) Filtering

The displayed data can be filtered using the reference parameter. In this interface, the center value and the range are designated separately by the sliders in left side.

4) Color Mapping

Point data are displayed in various colors according to the color parameters. The user can specify minimum value and maximum value to map the color value to the actual color. In this system, when the color value is less than minimum value, the data is visualized with gray color, and when the color value exceeds the maximum value, the data is visualized with white color.

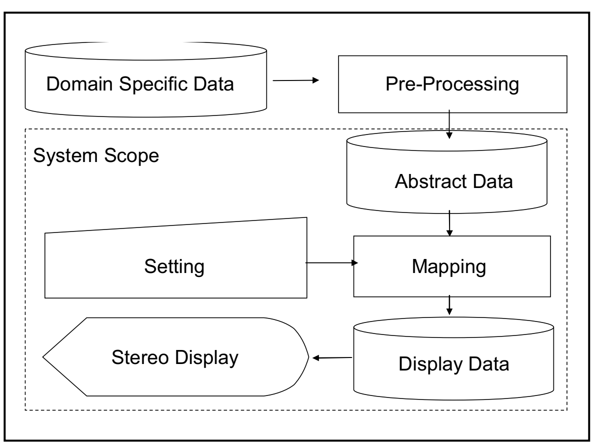

Figure 8. Data Flow in Visual Data Mining Platform

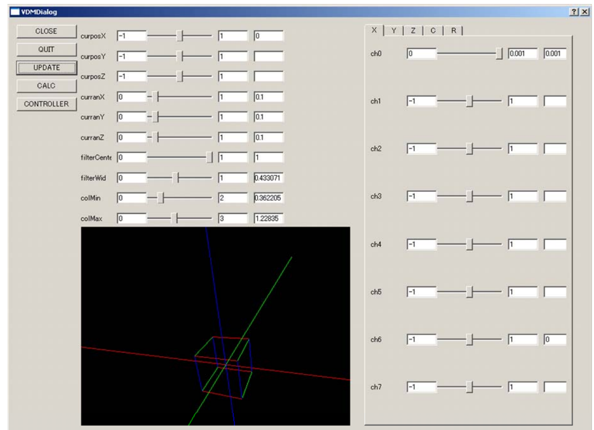

Figure 9. Snapshot of GUI Interface

5) View Point Control

The view point in the visualization can be controlled by dragging the cursor in the lower left region. This function supports the rotation of the view point around the arbitrary axis as well as the movement along the screen and perpendicular to the screen.

All parameters except for the view point are controlled with the GUI components, and these components were assigned to MIDI control channels. So, these parameters can also be controlled by the MIDI controller connected to the PC (See Fig. 10). Since the MIDI controller communicates with the PC using USB protocol, the control data are sent to the visual data mining system through the PC. Therefore, this controller enables the user to change the plural parameters simultaneously without looking at the console. Fig. 11 shows actual data mining scene using this platform. The user is operating the visual data mining platform using the PC console.

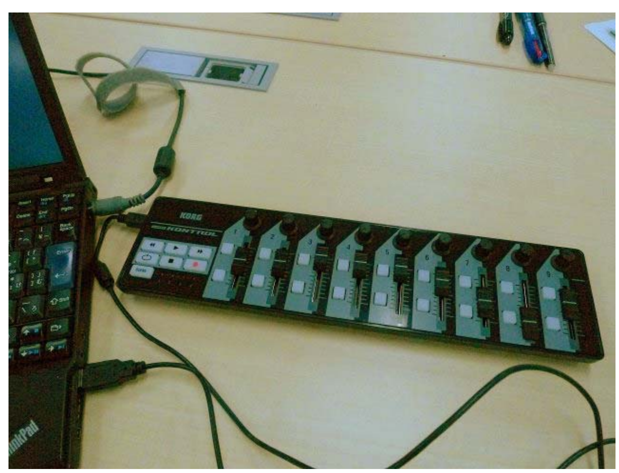

Figure 10. MIDI Controller connected to PC

Figure 11. Usage of Visual Data Mining Platform

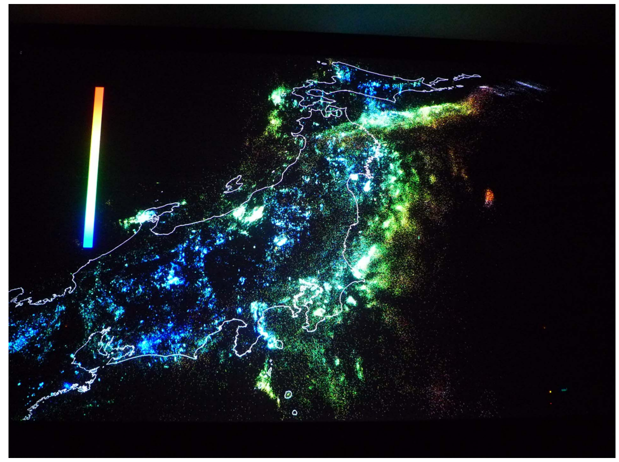

Figure 12. Visualized Seismic Hypocenters

V. APPLICATION TO SEISMIC DATA

We tried visual data mining on seismic data for the validation sake. In Japan, since a lot of earthquakes occur every year, it is very important to analyze the feature of the hypocenter distribution [8].

As the original data for evaluation, we used seismic hypocenter data from 2003 to 2007 that were stored in Hi-net [9] by National Research Institute for Earth Science and Disaster Prevention.

We visualized about 600,000 seismic hypocenter data with their magnitudes and occurrence times as well as more than 2 million data of pre-calculated b-values in Gutenberg-Richter (GR) relation. GR relation is a typical model to represent the distribution of magnitude of the earthquakes, and b-values can be calculated in the area designated in time and place. We also visualized coastal line of Japan overlaid by hypocenters, using the plug-in function of Open CABIN Library.

Fig.12 shows the visualization of seismic hypocenters colored with their magnitudes. The user can recognize the tendency of the earthquake distribution from the detailed stereo image. Fig.13 shows another example in which the occurrence time of the earthquake is mapped to height. From this image, the user can see small aftershocks sweeping long tails. In both cases, b-values are not being displayed using the filter parameter.

Fig.14 shows the visualization of b-values calculated for all seismic hypocenter data. In this image, seismic hypocenters are displayed in white color by the color mapping function of the platform. Because there are too many points distributed uniformly, the points inside the distribution are hardly recognizable and even the stereo vision is also difficult. Fig.15 shows the visualization of same data filtered by time span parameter. With this reduction of displayed points, users can recognize the feature of spatially distributed data. These representations of data were acquired from the same abstract data set by the user's interactive data manipulation.

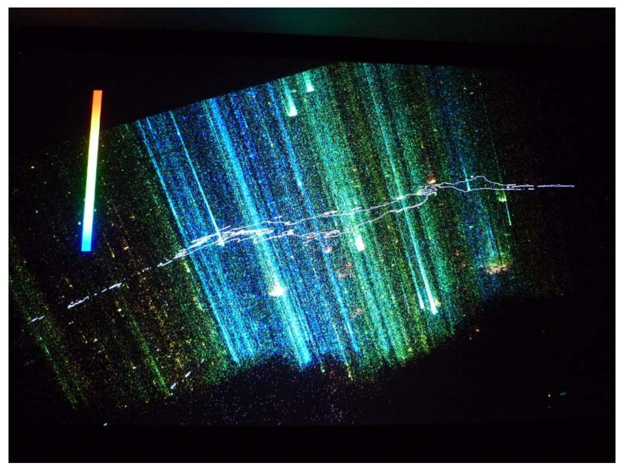

Figure 13. Visualized Seismic Hypocenters (Occurence Time Mapped to Height)

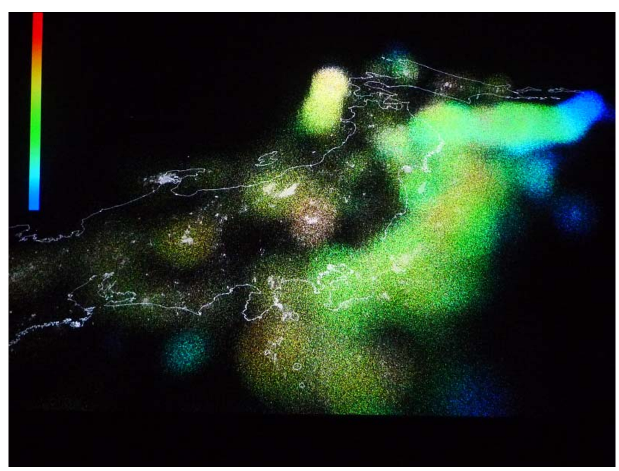

Figure 14. Visualized B-Values

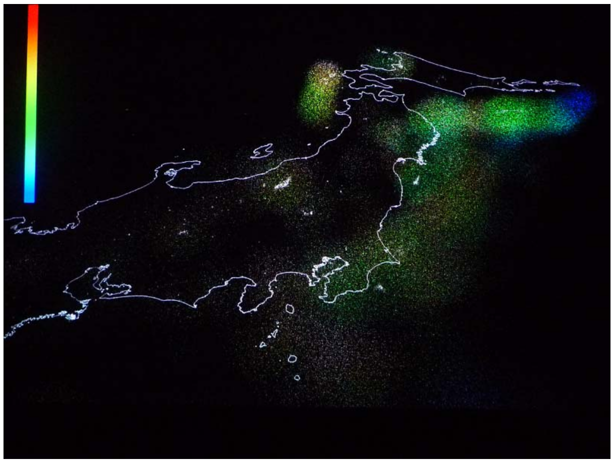

Figure 15. Visualized B-Values(Filtered by Time Span)

VI. CONCLUSION

Highly automated data processing can reduce the displayed data drastically, but it may sieve the insight on the other hand. So, balancing data representation with data processing is very important in visual data mining. And rapid progress of the display devices brings changes in scientific visualization and visual data mining. Namely, by using the advanced display devices, the relatively simple visualization methods, such as point cloud representation, may increase the efficacy especially in the early stage of data mining.

In this paper, we used super high definition stereo display environment to visualize large amount of spatially distributed point data. From the experiments, it is suggested that human factors (i.e. cognitive limitations) may be a new bottleneck in visual data mining cycle. General data reduction process which preserves mesoscopic structure of data can be useful if it is realized in future research.

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Japanese coastal line data are from Geographical Survey Institute.

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REFERENCES

[1] M. Kantardzie, “Data Mining: Concepts, Models, Methods, and Algorithms,” Wiley-IEEE Press, 2002

[2] D. A. Keim, “Information Visualization and Visual Data Mining, ” IEEE transactions on visualization and computer graphics, Vol. 7, No.1, pp 100-107, 2002

[3] E. J. Wegman and Jurgen Symanzik, “Immersive Projection Technology for Visual Data Mining,” Journal of Computational and Graphical Statistics, Vol. 11, No. 1, pp 1-26, 2002

[4] H. R. Nagel, E. Granum, and P. Musaeus, “Methods for Visual Mining of Data in Virtual Reality,” Proceedings of the International Workshop on Visual Data Mining, pp. 13-27, 2001

[5] T. Ogi, Y. Tateyama, and S. Sato, “Visual Data Mining in Immersive Virtual Environment Based on 4K Stereo Images,” 13th International Conference on Human-Computer Interaction(HCI International 2009), Virtual and Mixed Reality, LNCS 5622, Springer-Verlag, pp. 472-481, 2009

[6] T. Ogi, H. Daigo, S. Sato, Y. Tateyama, and Y. Nishida, “Super High Definition Stereo Image Using 4K Projection System,” ICAT 2008, Proceedings of 18th International Conference on Artificial Reality and Telexistence, pp. 365–366, 2008

[7] Y. Tateyama and T. Ogi, “OpenCABIN Library for Developing Applications in Large Display Systems,” ASIAGRAPH 2009 in Tokyo Proceedings, Vol.3, No.1, pp47-48, 2009

[8] T. Furumura and B.L.N. Kennett, “Subduction Zone Guided Waves and the HeterogeneityStructure of the Subducted Plate: Intensity anomalies in northern Japan,” Journal of Geophysical Research 110, B10302.1–B10302.27, 2005

[9] Y. Okada, K. Kasahara, S. Hori, K. Obara, S. Sekiguchi, H. Fujiwara, and A. Yamamoto, “Recent progress of seismic observation networks in Japan –Hi-net, F-net, K-NET and KiK-net,” Earth Planets Space, 56, xv-xxviii, 2004