VOV: Interactive 3D Geo-application for Visualization of Volcanic Eruptions via Smart Devices and LED Cube

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ABSTRACT

We present a comprehensive visualization of the provided data from the contest that enables domain experts to gain a deeper understanding of the volcanic eruption events and helps them better understand the consequences for atmosphere and climate. This paper deals with the contest tasks' solution and methods for data analysis. The VOV system is implemented to show time-dependent data visualization for domain experts and most people who has a smart device. New method geo-visualization using RGB LED Cube would be fresh to person who wants to get geo-information.

Keywords: Visualization, data analysis, interaction, time-dependent data, led cube.

1 INTRODUCTION

Multiple satellite data from different instruments affects strongly on studying natural events. Especially, the visualization of the satellite data shown in three volcanic eruptions enables researchers to get insights of their study on volcanoes and that following some effects. In 2011, there were all three main volcanic eruptions in the southern hemisphere and the northern hemisphere. At that time, the large amount of ash and sulfur dioxide was entered into atmosphere. However, the lack of global aerosol monitoring systems has called the weakness of alternative plans.

By integrating the given data in a common reference frame, the strong points of MIPAS, AIRS and CLaMS trajectory are revealed in visualization. And 3D/4D visualization is introduced to this system for showing the integrated outputs of all three modalities. For the researchers' insights on study, there are mainly two modules: the portable smart device and RGB LED cube as hardware. First, variable simulations via smart device can be controlled by a simple user interface. It allows the domain researchers understand a whole flow of aerosol detections. Second, the RGB LED cube gives users a specifically spatial visualization and the additional aesthetics. The two modules work through a wireless communication called Bluetooth and are communicated by users' simple touch.

This paper simply deals with this system's the methods of data analysis and introduces VOV system with some images.

2 THEORY

2.1 Dynamic Representation for Time-dependent Data

When the visual representation changes dynamically over time and is a function of time, it is called 'Dynamic Representation'. It makes direct use of time to depict some data. It is able to demonstrate the general temporal behavior, the dynamic of data and processes very well.

To guarantee the perception of continuous movements and changes the rate of repetition of images must be high enough to guarantee smooth motion from frame to frame. The reason for this is related to the sensibility of the human visual systems.

In general, a positive scaling factor s is used to adjust the duration of the animation appropriately, leading to

$$t' = s \cdot (t - t_{start}) \qquad (1)$$

Where t' denotes the animation time.

- Time-lapse visualizations ($s < 1$)
- Real-time visualization ($s = 1$), and
- Slow motion visualizations ($s > 1$).

2.2 Filtering & Sampling

As the data reduction methods, filtering and sampling techniques select a subset of data, to which standard visualization techniques can be applied. The selected subset, however, may still be too large to visualize effectively and may omit elements of interest. In simple random sampling every data point has the same probability of being selected. The sample resulting may not be representative and can miss important structures or outliers. Systematic sampling sorts data points in a particular order and selects data points at regular intervals with a random start. Stratified sampling divides a data set into disjoint subgroups or "strata", and applies simple or systematic sampling within each stratum. However, these methods require that specific dimensions be chosen ahead of time, requiring prior knowledge and often costly pre-processing.

3 DISCUSSION

Our visualization and analysis techniques are implemented on the following tasks:

- How can the temporal evolution of eruption events be visualized?
- How can the Grímsvötn and Nabro eruptions be separated?
- What does AIRS add to the overall picture?

To solve these tasks, we analyze satellite data and make application for visualization.

3.1 Data Analysis Techniques

To visualize the temporal evolution of eruption events, separate the Grímsvötn from CLaMS trajectories of Nabro and integrate MIPAS and AIRS, we analyzed the provided data in a common reference frame. To analyze the data, we utilize MySQL and Microsoft Excel in using .csv file format.

3.1.1 MIPAS detections linked to CLaMS Trajectory

1) Filter the ash or sulfate aerosol from MIPAS detection. The seed id is respectively connected to the detections.
2) Name the seed id which connected to first detection 'group1'.

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3) Name the start point of the seed id's backward trajectories 'individual 1'. And let next points be '2', '3', '4'… (Remove the afterward trajectories.)
And upload .csv file to DBMS.

3.1.2 Integrating MIPAS and AIRS

We use the MIPAS altitude data to pinpoint the vertical extent of AIRS detections. The two instruments' strong points are combined in common time, longitude and latitude. AIRS' satellite imagery has a 3-hour interval and MIPAS has an 11-days interval. It is almost 90 times.

To reduce and combine the two data, sampling is introduced.

1) Choose the only one from 200 data using MySQL query statement. It makes the interval broaden.
2) With MIPAS data, do mapping on common time.
3) Make new data set including latitude, longitude, altitude, time, ash concentration and SO2 concentration.

The new combination data has good abilities on accurate detection of particles and concentration check in a detail.

3.1.3 LED Cube Mapping

The LED Cube spec is the number of 8x8x8(512) and all things is consist of RGB LEDs. We can easily various colors of some instruments' detection. It is controlled by Arduino and shift register. And the size is $40cm^3$.

1) When you watch the data visualization via Smart Device, you can touch the one rectangle on image.
2) If you touch the one, more detail spatial information like x, y, z is changed to fit in the cube coordinates.
3) To reduce the scale, the equation is $(x', y') = (x/Tx, y/Ty)$. At first, divide 8 parts depending on maximum and minimum value. And then the algorithm for mapping to 8 LEDs is applied.
4) Like ash is purple color(G, B), SO2 is yellow color(R, G), Ice is blue color(B).
5) On the same time, the user can understand which position has which detection.
6) Additionally, brightness can show the high concentration of ash and SO2.

3.2 Data Visualization

We create the data visualization by using the color, time, spatial representation, and etc.

3.2.1 Visualization Factor 1: Color

The brightness in color is useful to draw the high concentration of ash and SO2. The individual color of ash, SO2, and other particles lets the user recognize the existence of them. We draw ash in dark color and SO2 in yellow.

3.2.2 Visualization Factor 2: Time

All datasets are registered in common geographical frame of reference defined by global latitude, longitude, and time. Especially, in our visualization, the experts can see how the particles in MIPAS detection are changing and what kind of particles are being at that time. The use of time frame makes the graphical scenes plentiful by creating the dynamic representation.

3.2.3 Android Application

Why do we use 'Point' visualization? Point is good for faster renderer than other 3D shapes. Especially, x, y, z is drawn in a simple design.

Why do we choose 'Touchable Device'? We thought that 'Touch' is the best of human's behaviors for getting information.

1) MIPAS: it gives 4 detection choices including all, ice, ash and sulfate aerosol for users. The users can choose only one to see visualization. The frame rate and time bar has same rate so the experts get live time-based flow of MIPAS detection.
2) MIPAS + AIRS: horizontal and vertical integrated drawings including the concentration of ash and SO2 are shown on the map.
3) Temporal Eruption: it is consist of MIPAS detection and the following CLaMS trajectories in Puyehue volcanic eruption. To match the ash and that trajectory on same time frame, seed id is required in finding ash detections. The one yellow circle shows detected position and temperature depending on the timeline. The following brown points are trajectories of the first head detection.
4) Grímsvötn Discrimination: it is consist of MIPAS detections and CLaMS trajectories in Nabro volcanic eruption. The seed id is required in finding sulfate detections on same time frame. Instead of showing all trajectories, it has a straight line connected the detection with the last tail of trajectories.

3.2.4 LED Cube

Our new method for visualization represents to RGB LED Cube. The reason why we consider this method is that we want to draw MIPAS' altitude or MIPAS with AIRS combination well. It is 3-Dimensional item so it's suitable to apply to spatial visualization. It gives the experts and scientists new interesting interaction via Smart device and RGB LED Cube.

4 Conclusion

We create the aesthetic hardware and mobile application for visualization of volcanic eruptions. Getting new experience of the domain experts is helpful for their research. Not only the experts but also normal users in anywhere can use this application easily. We hope that it could be extended to Table tablet for public display or on show.

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Figure 1. main screen (has buttons)

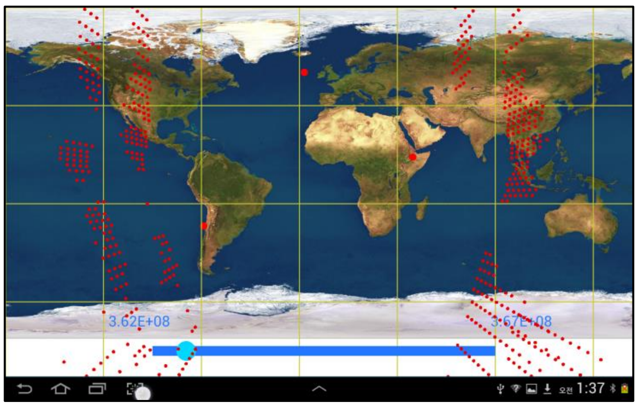

Figure 2-1. MIPAS visualization – Task1(ash only)

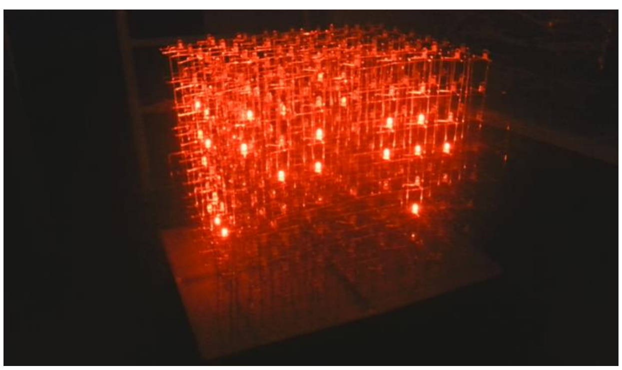

Figure 2-2. MIPAS visualization – Task1(ash only)

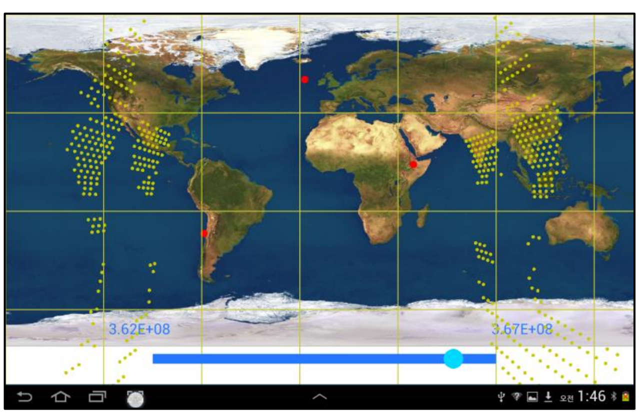

Figure 3-1. MIPAS visualization – Task1(sulfate aerosol only)

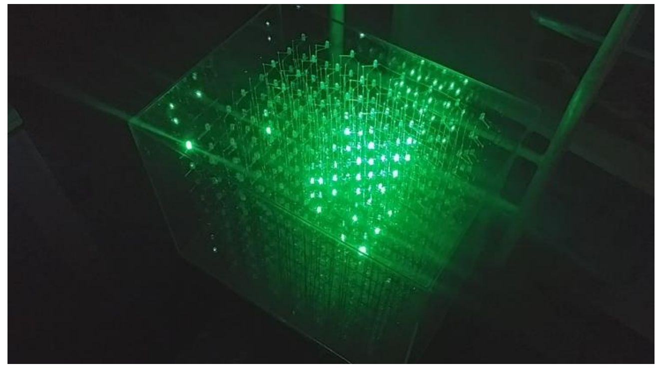

Figure 3-2. MIPAS visualization – Task1(sulfate aerosol only)

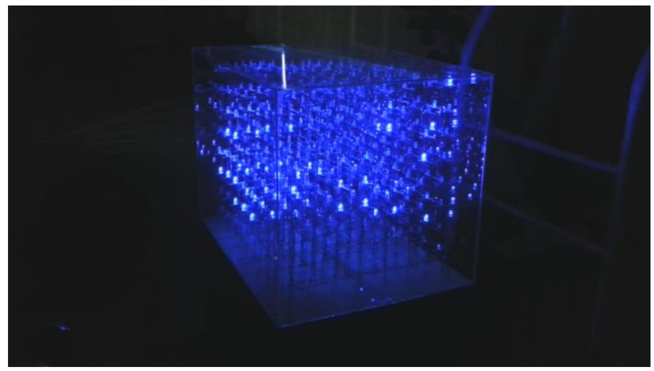

Figure 4. MIPAS visualization – Task1(ice only)

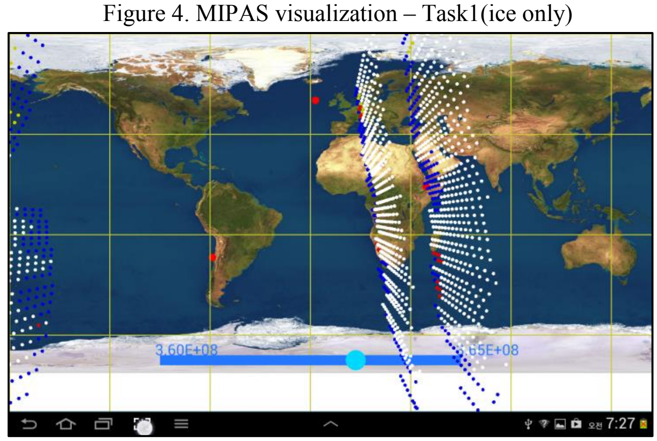

Figure 5. MIPAS visualization – Task1(All)

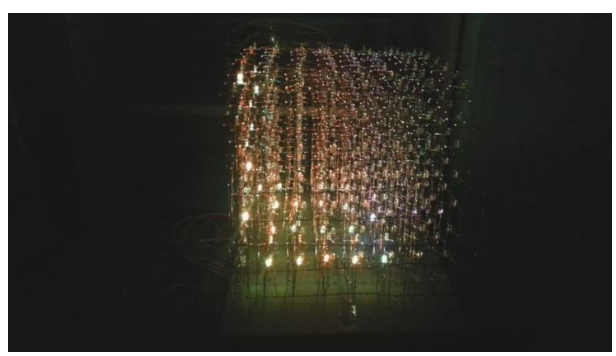

Figure 6. MIPAS + AIRS – Task3(SO2 concentration)

Figure 7. MIPAS + AIRS – Task3(ash concentration)

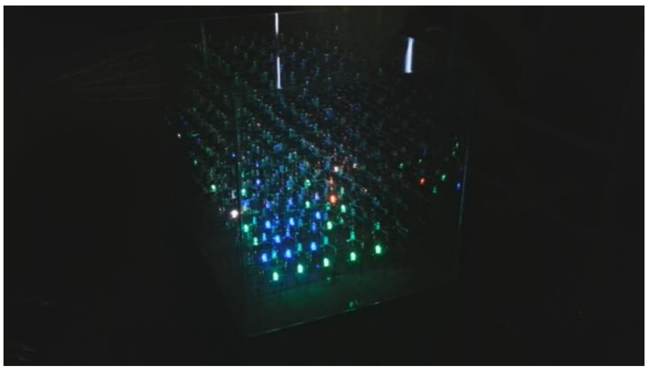

Figure 8. MIPAS + AIRS – Task3(SO2 + ash)

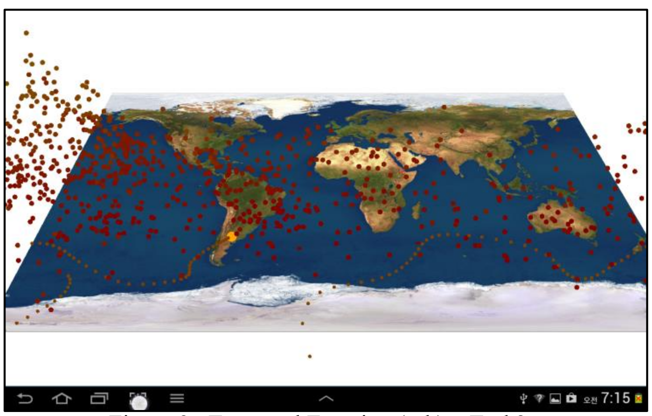

Figure 9. Temporal Eruption (ash) – Task2a

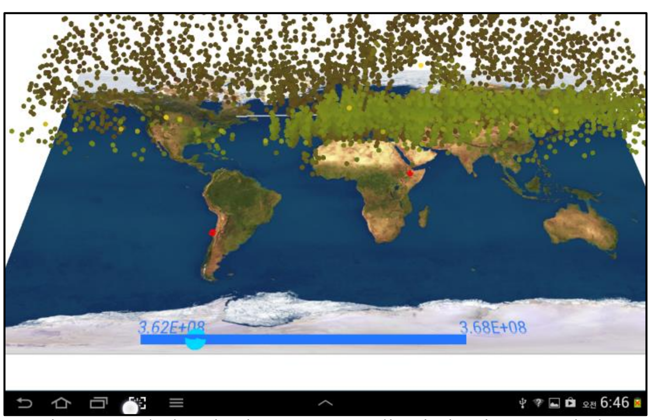

Figure 10. dark color is Grímsvötn discrimination – Task2b