Visualization and Analysis of Currents and Temperature Distribution Based on Ocean Data (Abstract)

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1 Introduction

According to the existing theories, the fishing hauls have a relationship with the distribution of temperatures and vortices. When warm currents meet cold currents, warm currents lift the nutrients in cold currents up to the shallow part of the sea, which makes a favorable environment for the reproduction of plankton, and thus the plankton-eating fish will be attracted. Besides, many kinds of fish move with currents, hence the fish density may be relatively higher at the confluence of warm currents and cold currents. Vortices also help to gather nutrients and fish. To find the relationship between these factors, some visualization methods need to be applied to our system. In this paper, we propose a system which is composed of overall and detailed visualization tools in order to verify the relationship between these factors. As for the visualization tools, we develop a parallel coordinates plot to show the overview of the high-dimensional ocean data, a streamline tool to show sea currents and a volume rendering tool to show the distribution of temperatures.

In the streamline tool, the 3-dimensional currents velocity field is visualized by streamlines with the starting points very close to vortices. Therefore, the features of these vortices are illustrated intuitively and we can find some typical vortices by comparison. The volume rendering tool is used for visualizing the overall distribution of temperatures. In the volume rendering view, a powerful tool is developed for user to customize the transfer function so as to emphasize some significant information and ignore the minor part. By ortho-slices, the 2-dimensional distribution of temperatures with different depths can be shown respectively as 2D plots, which is useful for us to understand the details of the internal distribution.

2 Related Works

The study on the relationships between the fishing hauls of squids in the sea area in Japan and the hydro-graphic conditions was first proposed by Suzuki in 1963[3]. This study explains why squids tend to migrate to "boundary zones" where different water masses meet each other and create prolific fishing areas. We try to get the same results as this study but using modern techniques of visualization to make a system allowing users to view and select the useful information in the data conveniently. Not only the fluid visualization, but also the flow visualization has been a primordial subject for researchers in a wide range of scientific fields. A lot of different rendering techniques has been developed[1]. From all those techniques, we use the volume rendering to visualize the distribution of temperatures in the ocean. Vortices are important features in flow research and visualization. Studies concerning vortices detection have been introduced by Sadarjoen et al.[2] and the scale calculation method for vortices proposed by Guo et al.[4] is applied to our system. Parallel coordinates plot is used in our system for providing an overview about the high-dimensional ocean data. To solve the cluttering problem, the *k*-means algorithm, which is introduced by Hartigan [5] and improved by Hamerly [6], is utilized to partition the input data into a number of partitions.

3 Proposed System

3.1 Overall Exploration of Data

Parallel coordinates plot is widely used for visualizing and analyzing multivariate data. In a parallel coordinates plot, each dimension of the input data is plotted as a vertical axis. Different with the Cartesian coordinate system, all of the axes are parallel with each other and a data point is plotted as a polyline connecting the corresponding positions on these axes so that it is possible to show more than three dimensions in a 2D plane. Therefore, parallel coordinates plot is a good way to provide the overview of the ocean data. Users can pick up the data points that they want to pay attention to by simply select the relative range on one or more axes. Furthermore, when the size of the input data is extremely large and the whole data can not be read into the main memory, the out-of-core feature can be utilized to process every part of the data sequentially. Only a part of the data is loaded at a time and after the calculation, the present data will be deleted from the memory and the next part of data will be loaded and processed. This procedure will be repeated until all of the data is processed. The high-speed *k*-means clustering method[6] can be used to solve the cluttering problem that when the number of data points is very large and it is difficult for users to discern so many lines. The input data is partitioned to a number of clusters and each cluster is plotted as a polygon in parallel coordinates, which accelerates the rendering as well.

3.2 Extraction of Vortices

In our system, the types of vortices are determined by the directions of vortices. In a horizontal plane, the directions of vortices can be divided into two cases: the direction of the currents in a vortex points toward to its center or far away from it. Similarly, in vertical direction, we can also divide the direction of currents into two cases. Therefore, there are four types of vortices in our system, which are detected by checking the real parts and imaginary parts of the eigenvalues of the Jacobian matrix calculated from the vector field of the currents in a vortex region.

To detect vortices from a vector field, firstly we calculate a critical point where the velocity vector vanishes. Then, we evaluate the Jacobian matrix J, which is a vector gradient tensor, from the vector field at the critical point in a cell. Then the eigenvalues of the matrix J are calculated. If there are two conjugate complex eigenvalues, the critical point is categorized as the center of a vortex.

Streamlines are used for visualizing sea currents in our system, especially the sea currents around vortices. By streamlines plot, we view and analyze the shape and the range of vortices. We suppose that the scale of a vortex to be mainly determined by the range of it. The cross method[4] is used for detecting the range of a vortex and the radius of a vortex can be figured out. By specifying the threshold value of the radius, our system can pick up the vortices above a certain scale.

3.3 Distribution of Temperatures

Volume rendering is used to visualize three dimensional data without imposing any geometric structure on it. It is applied to our system to show the distribution of temperatures. Because the temperature data is converted from the volume data with uniform grids, it is appropriate to use volume rendering to render the input data.

By adjusting the transfer function, it is possible to view the internal structure of the 3D object rendered by volume rendering. Besides, another method named orthoslice is also utilized in our system to visualize the distribution of temperatures at a certain depth. In our system, the proportion of depth can be specified by users. A proportionality factor $k \in [0, 1]$ is used for representing the proportion of the height from the bottom of the sample ocean data. Assume that D is the total depth of the ocean and d is the depth from the ocean surface, the equation used to calculate the depth d will be

$$d = (1 - k)D \tag{1}$$

Besides, the orthoslice and streamline can be shown simultaneously so that we can compare the position of vortices and the distribution of temperatures to analyze the relationship between them.

4 Experimental Results

We select the ocean data near Aomori in Japan as the sample data. The overview of the input data is visualized as clustered parallel coordinates, which is shown in Figure 1. The vortices with radii over 50 kilometers have been extracted and the result is illustrated as Figure 2. In this figure, vortices are plotted as streamlines and the small arrows show the direction of the sea currents. The background is the orthoslice used for visualizing the distribution of temperatures. As mentioned in the previous section, the proportionality factor k is customizable to set the proportion of depth. A smaller value of k makes the slice close to the sea surface, while a larger value of k makes the slice close to the bottom of the sea. We set the value to 0.99 here to show the temperatures distribution near the sea surface. In orthoslice, the rainbow color map is utilized, meaning that the sea areas with higher temperatures are colored in red while the sea areas with lower temperatures are colored in blue. Therefore, the areas in yellow or green are considered as the areas where warm currents meet cold currents.

Figure 3 illustrates the distribution of temperatures by volume rendering. The color map of orthoslice is the same as that of orthoslice in Figure 2. The transfer function has been adjusted to set lower opacity values to the areas with lower temperatures and higher opacity values to the areas with higher temperatures so that only the areas with higher temperatures are emphasized and the internal structure of rendered volume object is can be viewed.

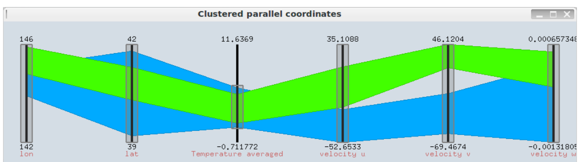

Fig. 1. Overview by Clustered Parallel Coordinates

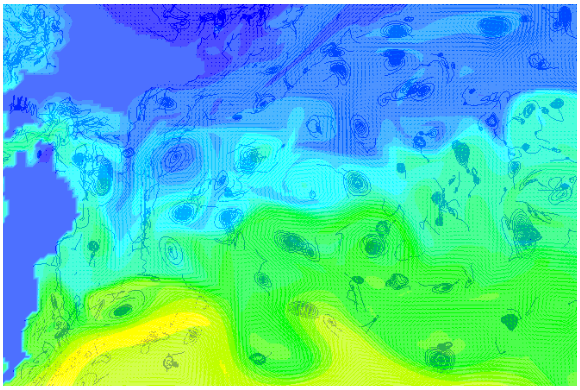

Fig. 2. Extraction of Vortices

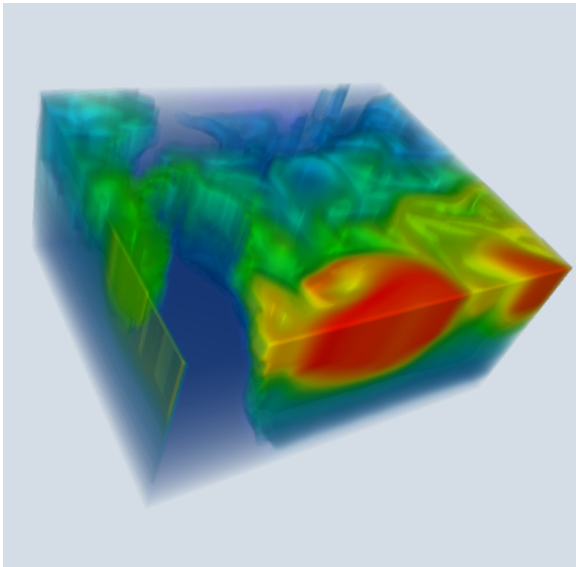

Fig. 3. Temperatures Distribution by Volume Rendering

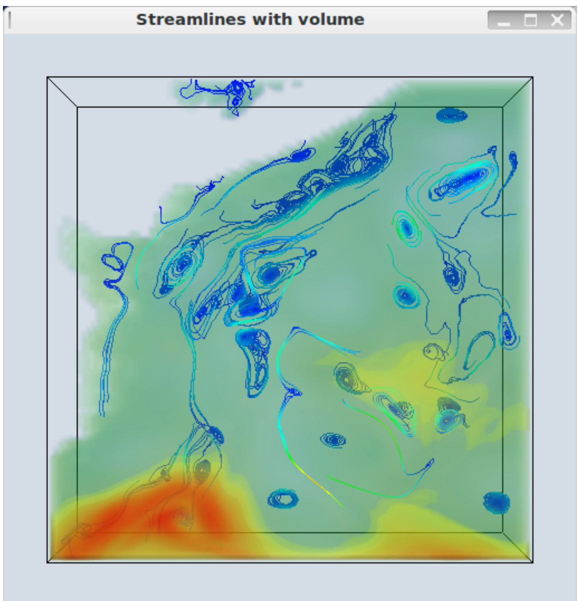

Fig. 4. Volume Rendering with Streamlines

The volume rendering and streamlines can also be shown together in one window as Figure 4. Different with the rendering result in Figure 2, both of the volume rendering view and streamlines are three dimensional. By adjusting the transfer function of volume rendering, we can emphasize the areas with the temperatures in a certain range and explore the vortices there.

5 Conclusions and Future Work

In our system, the vortices in the ocean data are extracted and their scale is able to be figured out. With volume rendering, the streamlines of sea currents and the distribution of temperatures can be displayed together in a window so that users can analyze the temperatures and vortices conveniently. In the future, the detecting and extraction of the upwelling with some typical types of vortices in three dimensions will be improved. Besides, the movement and changes of vortices will be traced and visualized in some proper ways. If the relationships between the climate change and the movement of the areas with high fishing hauls can be discovered, countermeasures can be taken to deal with the effect of the global warming.

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