Studies of Large-Scale Data Visualization and Visual Data Mining

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This paper reports activities of Advanced Visualization and Perception Research Group (AVPRG), Earth Simulator Center (ESC) in the fiscal year 2013. Research themes in this fiscal year are as follows: improvement of a volume visualization software in the EXTRAWING project, development of a mobile user interface in the VFIVE project and visual analytics approaches for ocean currents and eddies.

In the EXTRAWING project, we have been continuously developing VDVGE, a content-making software tool for realizing volume rendering-like representation on Google Earth. New functions, which are display functions of topography and coastline and an iso-contour drawing function on each slice of an input volume data, were implemented in VDVGE.

In terms of VFIVE project, the function to extract visualization operations by using a mobile user interface was implemented to VFIVE. This function divides the history of user's visualization operations into groups when each time interval between the operations is over a certain threshold. The user can select the groups of the operations and reapply to VFIVE.

Progress of visual analytics techniques for oceanic field datasets is summarized as follows: multivariate visualization approaches and pixel-based approaches. In terms of multivariate visualization approaches, we carried out case studies to represent multiple physical features of oceanic structure at once. As a result, effective visual representation of the features for ocean currents was obtained. In terms of pixel-based approaches, we developed a couple of the methods for extraction of vortices and segmentation of streams.

Keywords: advanced visualization, VDVGE, mobile user interface, visual data mining, ocean simulation data

1. Introduction

Amidst significant social change derived from the “big data” technologies, computer visualization has brought to much stronger attention than ever before. The same can be said for natural scientific domains. Scientific visualization is nowadays becoming more important, with the appearance of new data sources and research environments like cloud services in addition to experiments, observations and numerical simulations. We are carrying out basic researches in the field of scientific visualization in order to contribute earth-scientific communities. Our research interests covers wide-ranging area, such as large-scale data visualization using high-performance computers, application of virtual reality technology, visual analytics and graphical representation methodology. Especially in the fiscal year 2013, we have proceeded the three projects, EXTRAWING (Section 2), VFIVE extension (Section 3) and the development of the visual data mining methods for oceanic phenomena (Sections 4 and 5). In the following sections, we introduce recent progress of these projects.

2. EXTRAWING

EXTRAWING is a research project to develop methods to share earth-scientific knowledge among researchers and conveyer it to the general public, through attractive visual representation of numerical simulation and observation data [1]. Our aim of visual representation is to show three-dimensional features in simulation results on Google Earth (GE). We have already been developed a method to visualize volumetric structural data on GE as shown in Fig. 1 [2] and also a software tool, which is called VDVGE (Fig. 2), to make GE contents based on the method [3].

In the fiscal year 2013, additional visualization functions, displaying topography and coastlines and drawing iso-contours, were implemented to VDVGE. For the topography representation, three digital terrain models of different resolutions, ETOPO1 [4], ETOPO2 [5] and ETOPO5 [6], are available. This function is designed to be able to set the respective altitude scales of upper and lower side of sea surface independently in order to facilitate to visualize oceanic simulation data. For the coastline representation, GEODAS Coastline [7] is available. The optional function for command line execution was also added to VDVGE. VDVGE exports content files for GE without launching the GUI window. This function is effective to generate multiple GE contents automatically from a number of datasets by batch processing, whereas it is not possible to change the visualization configuration interactively during program execution.

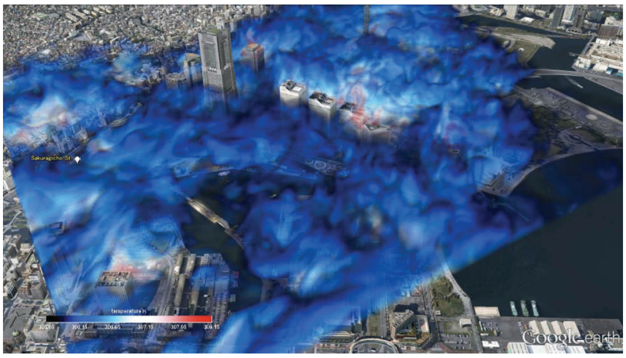

Fig. 1 Original volume representation method on Google Earth.

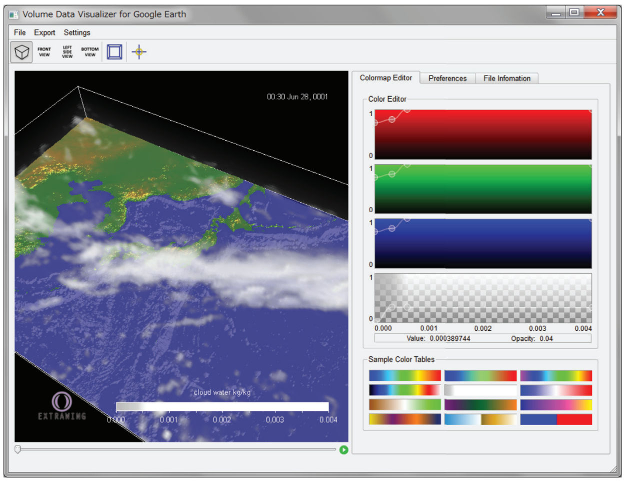

Fig. 2 Screen capture of Volume Data Visualizer for Google Earth (VDVGE).

3. Virtual reality visualization

Application of virtual reality (VR) technologies to data visualization is considered as an effective method to understand intuitively from given data. In particular, it is believed that immersive visualization environment as represented by a CAVE system [8] has a greater visual effect than the other VR devices such as a 3D-monitor and a head-mounted display because it covers the entire sight field of the user with multiple screens. We have installed the CAVE system called BRAVE [9] and continuously been developing VFIVE [10], a VR visualization software, shown in Fig. 3.

CAVE system, in general, strongly restricts user interface to portable devices like game controllers, because the system permits user's free movement and observation in the space different from desktop environment. Therefore, additional techniques are required for complicated manipulations such as character input, programming and optimal reconstruction of visualized objects. As for it, we are currently researching the methods to manipulate the system efficiently through utilizing mobile communication device like smart phone and analyzing human action. Shown in Fig. 4 is an example of the mobile user interface developed for VFIVE. In this picture, a list of the visualization operations that a user applied to VFIVE is displayed on the mobile user interface. The user can select some operations from this list and reapply to VFIVE.

In the fiscal year 2013, we implemented a function to extract visualization operations which satisfied with the specific conditions with a mobile user interface [11]. Here, we focused on time intervals between operations and assumed that time which a user observes scene became long when characteristic structures were visualized. We have carried out validation of the function, but it is not sufficient in number of the measurements. In the future research, it will be evaluated whether visualization operations extracted using this function lead to effective results.

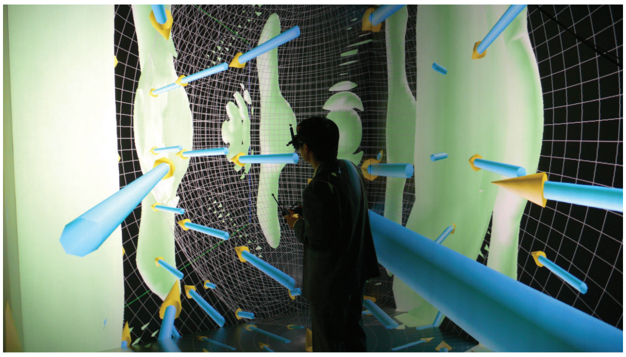

Fig. 3 VFIVE, Interactive visualization software for CAVE-type virtual reality system.

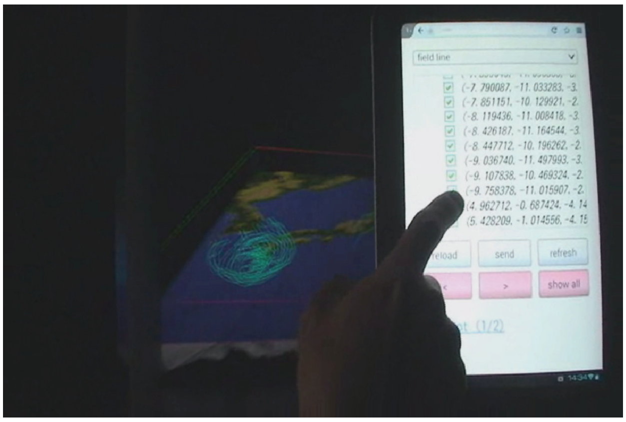

Fig. 4 Screenshot of the mobile user interface.

4. Multivariate visualization of ocean current

Global ocean simulation reproduces realistic ocean structures with a variety of physical characteristics. Ocean current, horizontal water streams in shallow ocean areas, has several physical properties such as current speed, velocity components, temperature and salinity. In order to investigate such properties of ocean currents, it is necessary to visualize multiple physical quantities simultaneously. This study attempts to visualize new aspects of ocean currents by means of multivariate visualization methods.

Figure 5 shows a visualization result of the Pacific Equatorial Countercurrent and its three velocity components (zonal, meridional and vertical components) using multivariate layering. Each component is represented by mixed color. Figure 6 indicates a visualization result of the same current and its six velocity components (eastward, westward, northward, southward, upwelling and downwelling components) using multivariate color weaving. Fine-grained structures of velocity components with each direction can be found without color mixing. In both cases, novel representations in which scientists can effectively recognize ocean currents and their physical characteristics can be obtained [12].

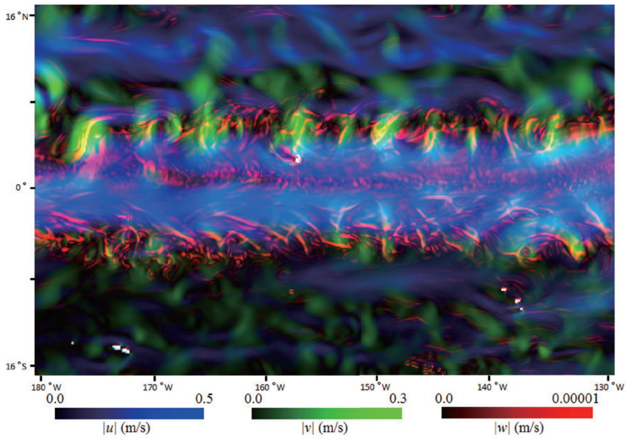

Fig. 5 Ocean current and velocity component: multivariate layering.

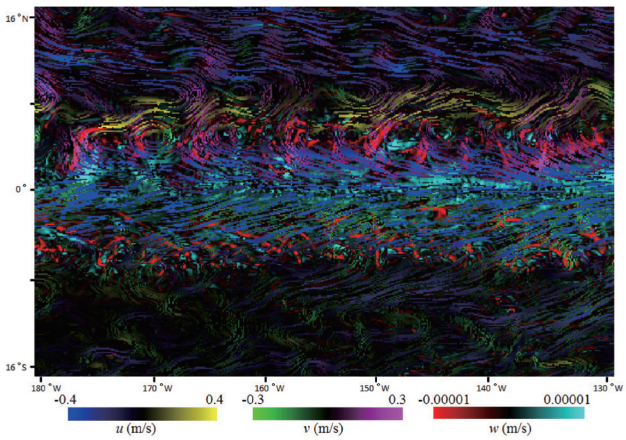

Fig. 6 Ocean current and velocity component: multivariate color weaving.

5. Extraction of vortices and segmentation of streams in the ocean flow field

The ocean flow field is mixture of innumerable multi-scale vortices and streams. They are highly intermingled intricately, and further, their boundary lines are ambiguous. Therefore, forms of these flows are indefinable. This makes us difficult to recognize the ocean flow structure. In this research, we extracted boundary lines of respective streams and vortices and visualized them to reveal the ocean flow structure. We propose independent extraction / segmentation methods for vortices and for streams.

The ocean flow field has vortex-core regions that mass do not mix with outer mass much. We define these regions are the regions to extract with our vortices extraction method. The saddle points, one of the singularities, can be appeared in outside of the vortices regions, and streamlines originated at the vicinity of the saddle points are expected not to enter the vortex-core regions because mass in the vortex-core regions do not mix with outer mass. Based on this consideration, we generated multiple widely spreading streamlines by seeding at the vicinity of the saddle points that have high Finite Size Lyapunov Exponent value, and extracted closed regions segmented with these streamlines if they include the center point (one of the singularities) inside. The extracted regions are regarded as the vortex-core regions. Figure 7 shows vortex regions obviously.

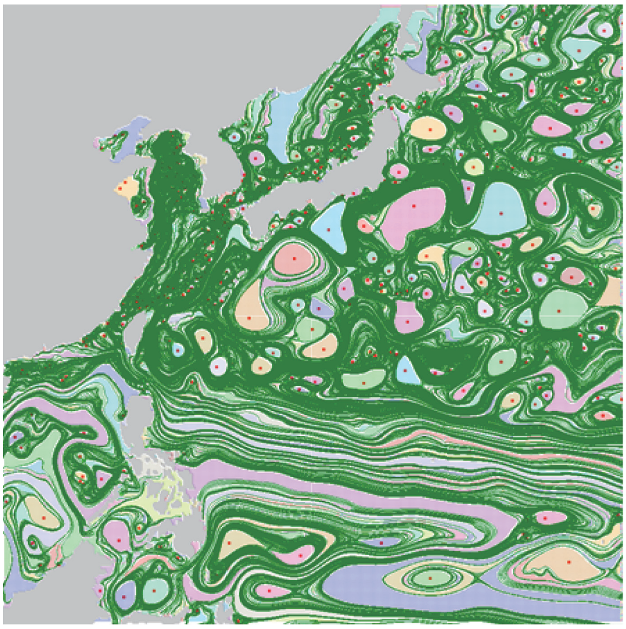

Fig. 7 Vortex regions with streamlines.

The individual streams are recognizable intuitively by regarding the stagnation points as terminations of each stream. In order to meet this recognition, our stream segmentation method firstly detect flow axis that is the series of the local maximum velocity points expanding to almost whole flow field without segmentation. The large detected axis can be segmented to axes of individual streams by removing points that has high velocity gradient between the adjacent local maximum points. This segmentation agrees to our intuitive recognition of termination of individual streams that is mentioned above. The residual points are associated to axes, and then all individual stream regions are determined. (Fig. 8)

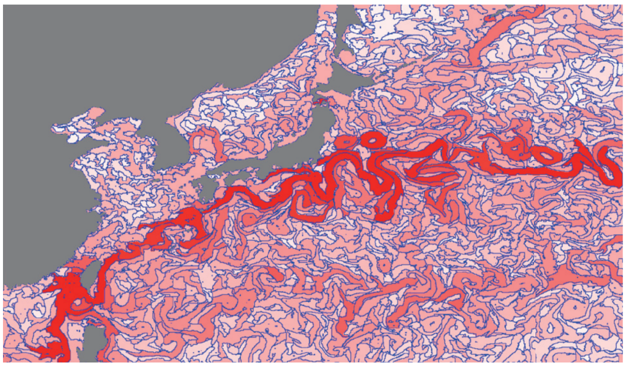

Fig. 8 Stream regions colored with internal velocity.

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大規模データ可視化とビジュアルデータマイニングの研究

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地球シミュレータセンター高度計算表現法研究グループの 2013 年度の研究成果について報告する。2013 年度の研究テーマは、EXTRAWING プロジェクトにおけるボリューム可視化ソフトウェアの改良、VFIVE プロジェクトにおけるモバイルユーザインターフェースの開発、海洋諸現象に対するビジュアルデータマイニング手法の研究開発である。

EXTRAWING プロジェクトについて、我々は Google Earth 上でボリュームレンダリング的な表現の 3D コンテンツを作成するボリューム可視化ソフトウェア VDVGE の開発を進めている。地形と海岸線の表示機能、入力データの各層上での等値線描画機能があらたに VDVGE に実装された。

VFIVE プロジェクトについて、モバイルユーザインターフェースを使って可視化機能を抽出する機能を VFIVE に実装した。本機能はユーザの可視化操作の履歴を、その操作の時間間隔がある閾値を超えるときにグループに分割する。ユーザはその操作のグループを選んで VFIVE に再び適用することができる。本機能は現在開発中であり、評価方法を検討している。

海洋場のデータセットに対するデータマイニング手法については、多変量可視化手法およびピクセルベース手法の研究開発を実施した。多変量可視化手法については、海洋構造の複数の物理的特徴を同時に表現するためのケーススタディを行った。その結果、海流および関連する物理的特徴の効果的な可視化表現が得られた。ピクセルベース手法については、海洋流れ場からの渦抽出手法およびストリーム分割手法を開発した。

キーワード : 先進可視化技術 , VDVGE, モバイルユーザインターフェース , ビジュアルデータマイニング ,
海洋シミュレーションデータ