

Visualization of Large-Scale Data by APRG, ESC

Project Representative

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1. Introduction

Advanced Perception Research Group of the Earth Simulator Center performs research and development on advanced visualization of large scale simulation data. The results in this fiscal year can be summarized as; (1) development of a parallel rendering software for scientific visualization of large-scale, three-dimensional, time development simulations; (2) development of 3-dimensional and interactive visualization software, VFIVE, for the CAVE-type virtual reality system.

2. Development of MovieMaker

On the Earth Simulator, it is not seldom that output data reaches more than 1 GB per one time step for a single variable. Since a typical simulation may produce the output data for several variables for hundreds or sometimes thousands time steps, the whole data set by one simulation job can reach more than 1 TB in total. Three dimensional, time development data should be visualized by a series of images, or a movie. However, making a scientific visualization movie from 1 TB data in a reasonable time is beyond the ability of commercially available software today. Therefore, we have developed such a software by ourselves.

We have designed MovieMaker as a master/slave parallel rendering program for the shared-memory architecture. The master process and slave processes have the simulation data stored in the shared memory area. The master process performs the following tasks; (i) to read a configuration file, (ii) to read the simulation data into shared-memory area; and (iii) to control the slave processes keeping a good load balance. Slave processes perform rendering tasks following commands sent from the master process and then return partial-images back to the master via shared memory. Interprocess communications are performed with Message Passing Interface (MPI). We have achieved the dynamic load balancing in MovieMaker by an active monitoring and dynamic control of the slave processes.

In addition to the dynamic load balancing, we have also implemented the task overlapping for efficient parallel rendering. While the slave processes are working on the rendering tasks for one specific time step of the simulation data, the master process reads data of the next time step. Since it may take more than a couple of seconds, to read a GB scale data for each time step from the hard disk drive, the total read time for the whole movie data may reach about an hour. We could hide this read time in the rendering time of MovieMaker by applying the task overlapping method.

MovieMaker is implemented in C++ with OpenGL. OpenGL is used for the off screen rendering. The present version of MovieMaker has three visualization methods: 1) volume-rendering; 2) isocontouring; and 3) streamlines. The volume rendering and the isocontouring are implemented based on basic algorithms of the ray casting and the marching-cubes, respectively. These three visualization methods can be used in juxtaposition. Fine-tuning of each visualization method is possible by controlling visualization parameters specified by a configuration file. MovieMaker, in the present version, adopts input data defined in the Cartesian

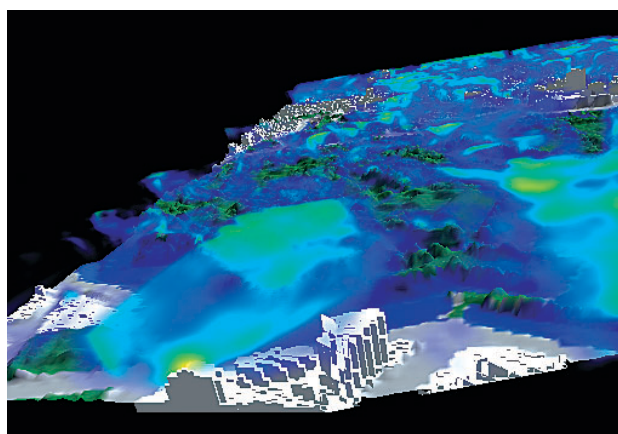


Fig. 1 A snapshot taken from a movie made by MovieMaker. The simulation was performed by Multiscale Simulation Research Group, ESC.

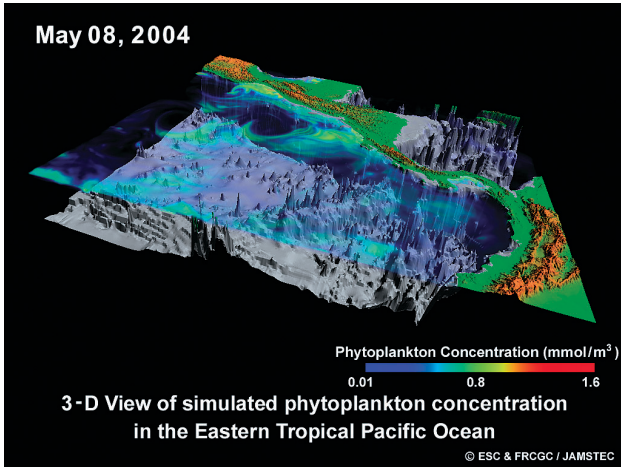


Fig. 2 A snapshot taken from a movie made by MovieMaker. The simulation was performed by Marine Ecosystem Model Group, FRCGC.

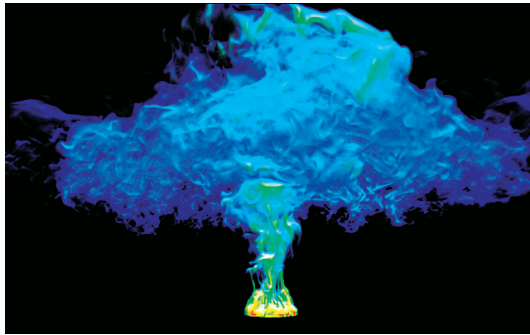


Fig. 3 Another snapshot taken from a movie made by MovieMaker; the eruption of Mt. Pinatubo in June, 1991. The simulation was performed by Research Program for Plate Dynamics, IFREE.

geometry. The grid system are supposed to be rectilinear, i.e., uniform and/or non-uniform in each direction of x , y , and z . Snapshots of MovieMaker are shown in Figs. 1, 2 and 3.

3. Development of VFIVE

The development of an interactive visualization environment for three-dimensional simulation data is one of the most challenging tasks for visualization researchers. We believe that the modern virtual reality (VR) technology, especially the CAVE-type VR system, provides the best solution today.

The CAVE is a room-sized, cubic-shaped VR system developed at University of Illinois, Chicago. We installed a CAVE system "BRAVE" in 2003. Stereo images are projected onto its $3\text{ m} \times 3\text{ m}$ screens of the walls and the floor. The viewer stands in the CAVE's room wearing a liquid crystal shutter glasses. A magnetic sensor is attached to the glasses so that the projected images are automatically adjusted to the viewer's position in real time. The stereo images for the four screens (3 walls + 1 floor) are generated by four DLP

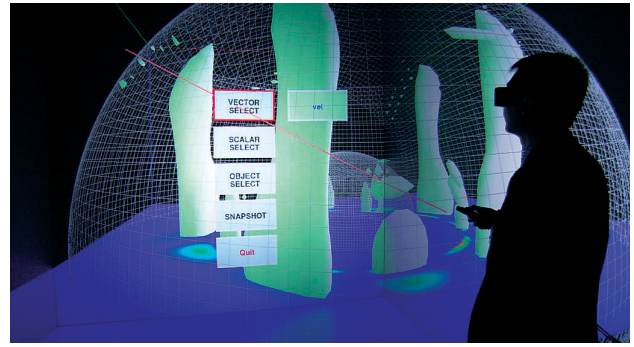


Fig. 4 VFIVE, a virtual reality (VR) visualization software for the CAVEtype VR system.

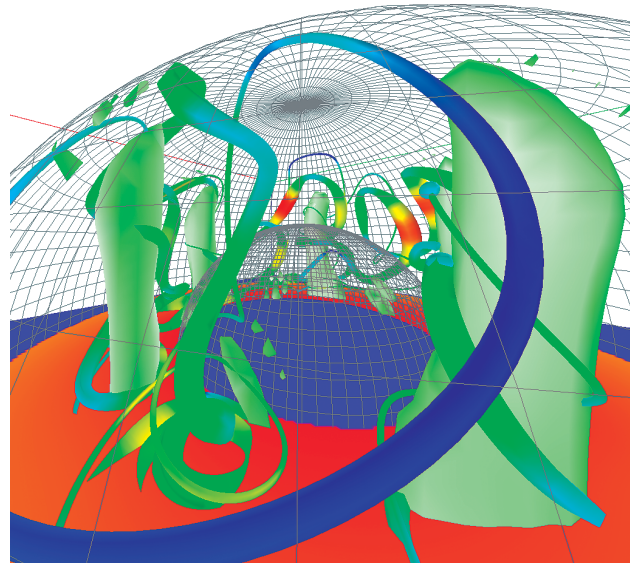


Fig. 5 A snapshot of VFIVE visualization. The tube-like stream line is generated by VTK combined into VFIVE.

projectors. Since they are projected seamlessly on their borders, everything looks natural from the viewer inside the CAVE and feels a deep immersion in the VR world. The viewer interacts with the simulation data through a portable controller. Another magnetic sensor is attached to the controller to detect its position and direction.

VFIVE is our original virtual reality visualization software for CAVE systems (See Fig. 4). VFIVE is a fully interactive visualization tool; we can control the isosurface level by the vertical motion of the wand in the CAVE room; we can start new tracer particles from the tip of the wand by pressing a wand button; and a spotlight is emitted by the wand and thousands of tracer particles are flying in the cone-shaped light. From the original version, VFIVE has basic visualization methods such as the isosurface and the stream line.

We added the following new features to VFIVE this fiscal year: (1) Combination of VTK with VFIVE (Fig. 5); (2) Integration of LIC (Line Integral Convolution) method to VFIVE; (3) Presentation of text data.

高度計算表現法研究グループにおける可視化研究

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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では、大規模シミュレーションの可視化に関する研究開発を行っている。今年度の主な成果は以下の3つにまとめることができる：(1)大規模データからの動画作成用ソフトウェアMovieMakerの開発。(2)仮想現実(Virtual Reality, VR)装置用可視化ソフトウェアVFIVEの開発。(3)その他、3次元版LIC (Line Integral Convolution) 法などの新しい可視化手法の研究開発。

時間発展を扱うシミュレーションデータの可視化には動画の作成が不可欠である。地球シミュレータにおける大規模シミュレーションでは一回のシミュレーションジョブで、合計1TB程度のデータが出力されることが珍しくない。これほどの大規模データとなると市販の可視化ソフトを用いて動画を作成することは実質上不可能である。そこで我々はMovieMakerと名づけた並列可視化ソフトウェアを新たに開発した。MovieMakerを用いれば、1時刻あたり1GB程度のデータが1000ステップ分あったとしても一晩(12時間以内)で動画を作成することができる。処理の高速化のためにMovieMakerでは：(1)MPIを用いたレンダリング処理の並列化、(2)マスター/スレーブ方式による並列レンダリング処理の監視と負荷分散、(3)データ読み込みとレンダリングの負荷分散(スレーブプロセスがレンダリングしている間に、マスタープロセスが次の時間ステップのデータをハードディスクからのデータ読み込む)、等の工夫を行った。

VFIVEはCAVE型VR装置を用いて3次元・対話的可視化処理を目的として我々が開発を続けているVR可視化ソフトウェアである。今年度VFIVEに対して我々が行った開発は以下の通りである：(1)可視化ツールVTK (Visualization Toolkit)を組み込んだ。(2)最近、注目を集めているベクトル場の新しい可視化手法LIC (Line Integral Convolution) 法を組み込んだ。(3)数字や文字列などテキストデータをVR空間内で表示できるようにした。

キーワード：可視化, MovieMaker, VFIVE