§28. Interactive Visualization of Time-developing Data in CAVE Systems

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The output data produced by numerical simulations of plasma are basically three-dimensional (3-D) and contain plural vector and scalar fields. With the increasing abilities of computers, the data is becoming larger and more complex. The simulation researchers must visualize and analyze their complex data to dig out and grasp phenomena hidden in their simulation data. Although this process is usually done at their desk by using PCs or graphics workstations with usual two-dimensional (2-D) monitors, it is hard and time-consuming to understand the complex 3-D data, especially vector fields, by using them. This burden has been increasing day by day. It is one of the reasons why researchers have been looking for new technology and why virtual reality (VR) systems, which enable them to visualize and analyze data stereoscopically, have been used as a visualization tool for analyzing numerical data. Among several VR systems, CAVE-type VR system[1)] (see Fig.1) is already seen as visualization apparatus and widely spreading. This kind of system has been used in many scientific fields since more than a decade ago from fluid data to archaeological data.

We have been developing an interactive visualization software for the CAVE-type VR systems. It is general-purpose and is called VFIVE[2-6)]. VFIVE enables users to visualize their numerical data by using basic visualization methods such as isosurface, color slice, volume rendering, field lines, arrows and so on. CAVE systems have three superior features as a visualization apparatus, being stereoscopic, immersive and interactive. We lay big stress on the last feature, interactivity, when designing VFIVE. VFIVE builds up interactive visualization and analysis environment in CAVE systems through Wand and does not make CAVE systems "3D object viewer". The Use can change the visualization parameters, and the change is soon reflected in the VR space. For example, the moment user changes the isosurface level, VFIVE begins to calculate the isosurface of new level and show it. VFIVE is not a software which displays only pre-calculated visualized objects. The visualization methods can be selected by menu function. By the menu function, a user can select target data and visualization method in the CAVE room. User need not go out of the CAVE room to select them by mouse or keyboard.

The operations of visualization method such as changing the parameters are intuitive and easy. For example, after selecting a vector data and field lines as visualization methods, seeds of stream lines can be placed in VR space intuitively. When a user pushes one of the buttons of the Wand, it begins to emit a laser beam. User can freely move wand in his hand and take aim at the point where he or she wants. When the user releases the button, two balls emerge at the tip of the laser beam and begin to follow and draw the stream lines. The Runge-Kutta integration starts after the release of the button.

By this collaboration, we add VFIVE to a animation function. By this function VFIVE can handle time-developing data. When a user activates the animation function, VFIVE begins to read data and visualize it by the same visualization parameter such as isosurface level and seeds of stream lines. The visualized objects such as isosurface are saved as OpenGL's display list, a kind of macro (or polygonal data are saved on hard disk drive (HDD) when the number of time steps is large). After completing this procedure at all time step, VFIVE begins to display the visualization objects of each time step one after another.

By the combination of the interactive user interface and the stereoscopic and immersive view, the CAVE system with VFIVE provides 3-D data (or 4-D data) analysis environment to the researchers.

This software can be downloaded from JAMSTEC's web site[7)].

Fig.1 A CAVE system at JAMSTEC.

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