Data Visualization by a Virtual Reality System

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1 CompleXcope VR System

There have been great advances in virtual reality (VR) technology in these several years. Everyone who experience recent VR systems would be surprised for its high quality of reality. It is a natural idea to apply the modern VR technology to the visualization of plasma simulation, since researchers of plasma simulation have always been challenged by the difficulty of visualization of very complicated three-dimensional (3D) structures that is beyond the power of the graphics workstations.

We have developed a virtual reality system named *CompleXcope* to analyze complex data obtained by supercomputer simulations. *CompleXcope* is a cubic room (10 feet side length) surrounded by white walls and a floor. Stereo images are projected onto two walls (front and right) and the floor by three projectors. The three large stereo screens (10 feet × 10 feet) guarantee large range of view angle which is important for reality production. The refresh rate of the image is sufficiently high (96 Hz). The images on the boundaries between the walls and the floor are so smoothly connected that viewers easily forget the existence of the boundaries. Simulation data are modeled and visualized by the standard graphics library OpenGL. People wearing stereo glasses stand in the room and observe the virtual objects in 3D from any position and direction. They look 3D objects in the 3D space. As their viewpoint moves (by walking or head rotation), the objects are properly re-rendered in real time. The scene is, therefore, very natural for viewers. They can easily interact with the VR world, too.

2 Virtual LHD

As a first application of *CompleXcope*, we have developed Virtual LHD program. The LHD (Large Helical Device) is a fusion experiment device under construction at National Institute for Fusion Science, Japan (in the real world). As in the real LHD, Virtual LHD has toroidal and poloidal coils and vacuum

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vessel. People see and walk through the virtual LHD in stereo in the real size or scaled size. The reality is so high that many people experienced *CompleXcope* for the first time stretched their arms trying to touch the coils.

Virtual LHD program reads MHD equilibrium data calculated by the HINT code which is one of the standard codes for the MHD equilibrium of helical systems. One sees magnetic surfaces, field lines, particle orbits, pressure isosurfaces in *CompleXcope*. Wonderful thing about Virtual LHD in *CompleXcope* is that everything appears in 3D with very high reality, and with flexible interaction. For example, one can interactively change the isosurface level by "touching" a virtual level bar in the *CompleXcope*.

Construction of *CompleXcope* was completed in September 1997. Virtual LHD program has been used as a powerful research tool from just after that time. *CompleXcope* is an application of one of the most well known and successful VR systems called CAVE which is developed at Electric Visualization Laboratory (EVL), University of Illinois. Refer to EVL's WWW page[2] for the details of the CAVE hardware and software.

3 Virtual Reality Experience

It is impossible to convey the reality in *CompleXcope* only by text and figures. Here we just try to describe a typical experience in the Virtual LHD program. People wearing stereo glasses in the *CompleXcope* room feel as if they were floating in the "air" when the Virtual LHD program starts. They see the virtual "ground" with checkerboard pattern and the LHD helical coil pairs far under their foot (Fig. 1).

By controlling the *wand*, a portable stick type controller with buttons and a joystick, they can move or "fly" in the virtual space in any direction as their wish. As they approach to the LHD, the helical coils look larger, and finally the coils are within their reach (Fig. 2). The pink object is an isosurface of pressure. The pressure data is obtained by the HINT code. (The actual scenes in *CompleXcope* are all in stereo.) It is easy to change the isosurface level, or remove the surface by the wand.

By pushing one of the wand button, tracing of a magnetic field line starts (Fig. 3). The starting point is the wand tip. So, it is easy to make field lines in a particular place; just reach out your arm and press the button of the wand in your hand at the position where you are interested in. The field line tracing is calculated every time when the button is pressed. This is an example of real time, interactive data analysis which would be possible only by VR.

Another button of the wand is used to see drift particle orbits in the LHD (Fig. 4). When the button is pressed, a drift particle with fixed energy is released from the wand tip. The starting pitch angle is controlled by the wand direction. Every time the button is pressed, a new particle is generated and its orbit is calculated by integrating the drift equation of motion under the magnetic field data obtained by the HINT code. As the integration goes on, the drift particle

[2]http://www.evl.uic.edu/EVL/index.html

moves in the LHD and its past trajectory is shown by a line. One of the most impressive experiences in *CompleXcope* is to watch a trapped particle motion with a complicated orbit under our noses (Fig. 4).

4 Summary

We have constructed *CompleXcope* VR system for the purpose of analyzing complex 3D data obtained by large scale plasma simulations. Newly developed Virtual LHD program, the first application of *CompleXcope*, demonstrates that *CompleXcope* is a powerful tool as a 3D data visualizer/analyzer.

Figure 1: Virtual LHD world seen in *CompleXcope*. It is actually projected onto three large stereo screens ($10 \times 10 feet^2$) of two walls and the floor of the *CompleXcope* room. The LHD helical coils are seen under the foot.

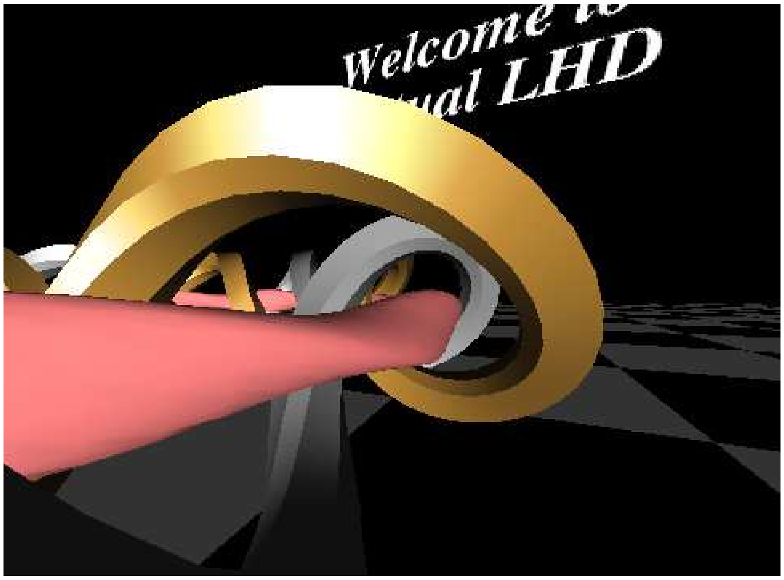

Figure 2: Helical coils and a pressure isosurface. By touching a level bar (not seen) by the *wand*, the isosurface level is interactively controlled. The wand is a portable controller with buttons.

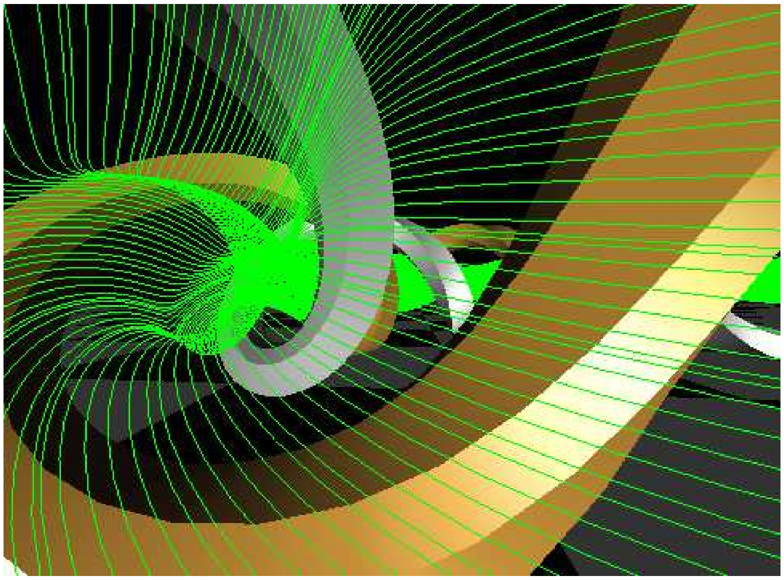

Figure 3: A magnetic field line. The field line tracing starts from the wand tip position when a button is pressed.

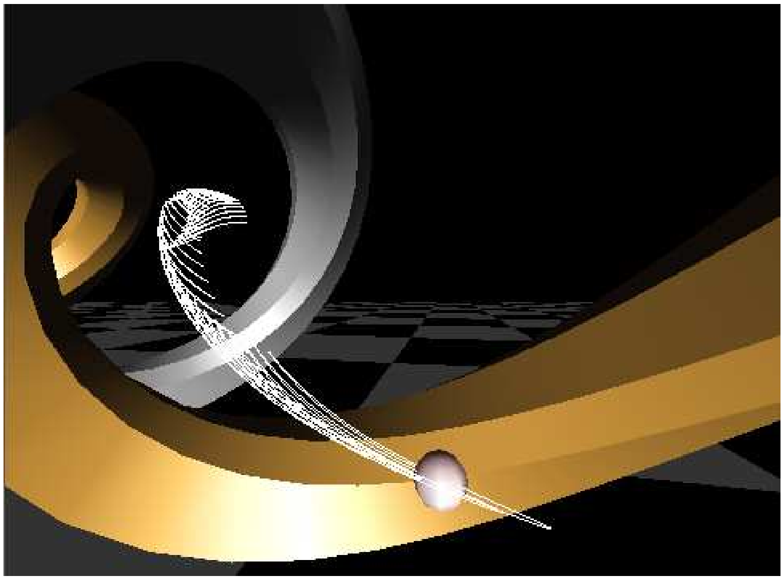

Figure 4: Drift particle motion. The integration of the drift equation of motion under the LHD field starts when another wand button is pressed. The starting point and the pitch angle are both easily and arbitrarily controlled by the wand. This figure shows a trapped particle motion.