Immersive Visualization of the Hurricane Isabel Dataset

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Abstract

In this paper, we describe an immersive prototype application, AtmosV, developed to interactively visualize the large multivariate atmospheric dataset provided by the IEEE Visualization 2004 Contest committee. The visualization approach is a combination of volume and polygonal rendering. The immersive application was developed and evaluated on both a shared-memory parallel machine and a commodity cluster. Using the cluster we were able to visualize multiple variables at interactive frame rates.

CR Categories: I.3.7 [Computer Graphics]: Three-Dimesional Graphics and Realism—Animation; I.3.7 [Computer Graphics]: Three-Dimesional Graphics and Realism—Virtual Reality

Keywords: immersive visualization, volume rendering

1 Approach

We developed AtmosV expressly for the hurricane Isabel simulation dataset provided by the National Center for Atmospheric Research. AtmosV was derived from the Immersive Drilling Planner, a visualization and planning tool for oil and gas wells, also developed at the BP Center for Visualization. The development team consisted of Kenny Gruchalla and Jonathan Marbach, both Ph.D. students in computer science at the University of Colorado. A demonstration video, screenshots, and a more in-depth discussion of this work can be found at http://www.jonmarbach.com/isabel.

We took an immersive visualization approach to the problem. This approach physically immerses users in a virtual world, where they can explore multiple variables of the dataset by looking through them, walking around them, and viewing them from an egocentric perspective. The demonstration video shows AtmosV in a Fakespace Flex^{TM}, a configurable large-screen projection-based immersive virtual environment (IVE). The Flex has four display screens that were driven by a commodity PC cluster with four nodes, each equipped with a Nvidia QuadroFX 3000G graphics card. A three-dimensional effect was created inside the IVE through active stereo projection. The data was interacted with using a wired InterSense wand, a three-dimensional, six-degrees-of-freedom pointing device with four buttons and small joystick. An InterSense VET 900 tracking system tracked the position and orientation of the users head and the wand. Tracking the position and orientation of the user's head allowed the user to move around in the virtual world and see that world from different perspectives.

We employed a combination of volume and polygonal rendering to allow users to explore multiple variables simultaneously. In our demonstration, total cloud moisture, total precipitation, and pressure are volumetrically rendered. Wind is visualized through an interactive vector-field plane. Two types of interactive probes provide information on scalar values. The system was written in C++ using OpenInventor and the VolumeViz OpenInventor extension from Mercury Systems. To achieve interactive volume rendering frame rates, the volume data was downsampled to the nearest power of 2 dimension, 256x256x64, using a box-filter method. The floating-point scalar volumes were converted to byte volumes at runtime.

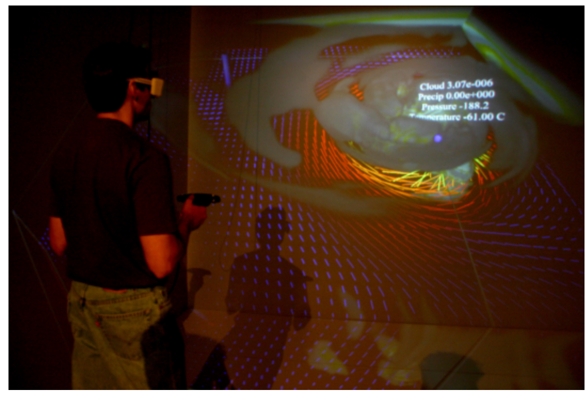

Figure 1: A user interacting with the immersive visualization. The photo shows volume-rendered total cloud data, a vector-field plane representing a slice through the wind data, and a text probe that displays total cloud, total precipitation, pressure, and temperature at a point in the data space. The data is visualized inside an immersive virtual environment, allowing the user to physically explore the data.

1.1 Interaction and Exploration

As an immersive application, AtmosV provides the users the ability to physically navigate and explore the data space. Two types of navigation are provided: *physical navigation* and *pointing*. Physical navigation maps a user's physical movements, such as walking, into corresponding motions in the virtual world. The pointing technique allows users to reach areas of the data space outside of the physical bounds of the IVE. Pressing forward on the wand's joystick will "drive" the user in the direction the wand is pointing. Pressing backwards on on the wand's joystick will move the user in the opposite direction. Pressing right or left on the joystick will rotate the scene around the user. The joystick is pressure sensitive and the amount of pressure exerted on it maps to the speed of travel.

In addition to the immersive navigation features, AtmosV provides three interactive three-dimensional widgets: a text probe, a vector-field plane, and a column probe. The text probe widget provides an interactive three-dimensional text readout of multiple scalar variables. The probe is manipulated by dragging a small sphere to an area of interest. As the sphere is moved, a text readout is updated. The text reports all scalar values available at the center of the sphere. In our demonstration, total cloud moisture, total precipitation, atmospheric pressure, and temperature are provided in the text readout; however, the probe can be configured to interrogate any of the scalar data variables.

The column probe provides a means to interrogate a column of

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a scalar dataset. This is achieved by presenting scalar values on a cylindrical surface through a texture look up. The columns can be interactively moved, allowing users to explore the data space. In our demonstration, the column probes display temperature; however, any of the scalar data variables can be interrogated using this probe.

The vector-field plane provides a mechanism to visualize the Isabel wind vector data. The wind vectors are rendered as lines. The length and color of each line is based on the magnitude of its corresponding vector. Users may move the plane to interactively choose which slice of the vector-field is displayed. The user accomplishes this by selecting and dragging the virtual plane with the wand.

AtmosV also provides an immersive transfer function editor, allowing the user to explore the volumetric space. Each channel of the colormap is displayed separately on a rectangular panel, allowing the user to edit the red, green, blue, and alpha components individually. As the user "paints" a curve onto any of the color-component panels, the opacity panel displays the composite RBGA color.

All the features of AtmosV can be accessed through a three-dimensional toolbar. Through this toolbar a user can control the current time step, start and stop an animation loop, switch between volumetric datasets, toggle the wind vector field, introduce text probes, introduce column probes, and access the immersive transfer function editor. Short-cut buttons on the wand are also provided to start and stop animation and to step forward through time.

1.2 Multivarite Visualization

Through a combination of both polygonal and volume rendering we are able to show multiple variables simultaneously. Our system will only volume render one scalar dataset at a time; however, using our three-dimensional widget-set, scalar and vector values at various areas of interest can be visualized concurrently with the selected volume data. For example, both Figure 1 and Figure 2 depict visualizations of multiple characteristics. In Figure 1, the user has selected the volumetric visualization of the total cloud data through the toolbar. In conjunction with the cloud volume, the user has placed a text probe near the storm clouds in the upper atmosphere and has dragged the wind vector-field plane into the lower atmosphere. In Figure 2, the user has selected the volumetric visualization of the pressure data, and edited the transfer function to highlight an area of low pressure. In conjunction with the pressure data, the users has dragged three column probes (representing temperature) and a text probe into the scene.

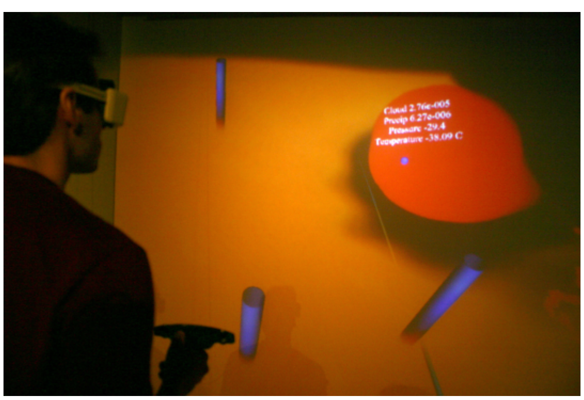

Figure 2: Visualization of multiple characteristics. The photo shows volume-rendered pressure data. The transfer function has been edited to highlight an area of low pressure. The user is shown interacting with one of the column probes that depicts a temperature column within the atmosphere.

2 Discussion

We evaluated the system on both the commodity cluster and a 20-processor SGI Onyx 3800 with four InfiniteReality3 graphics pipes. The Onyx has a 64-bit shared memory architecture that provided us with 20 gigabytes memory. Theoretically, the entire down-sampled Isabel dataset could be stored in RAM on this machine. However, the Onyx was not able to render the volumetric data at interactive frame rates.

As our video demonstrates, AtmosV is capable of visualizing multiple variables at interactive frame rates using the 32-bit cluster. However, the cluster has its own limitations, primarily memory. Each node of the cluster has only one gigabyte of memory, restricting our application to a sub-set of the data for any one execution. For example, this limited us to less than twelve time steps of cloud moisture, precipitation, pressure, temperature, and wind data. The floating-point wind triplet was the limiting factor: without loading the wind data, there were sufficient resources to visualize a complete forty-eight time steps of four scalar volumes with our application on the cluster. Clearly there are tradeoffs between the two systems. Since interaction was a driving goal of the contest, the cluster was chosen for the demonstration video.

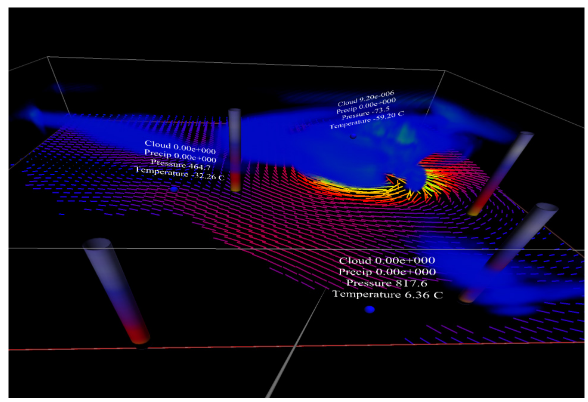

Figure 3: Screenshot of precipitation (volume rendered), wind vectors, text probes, and column probes.