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Commodity Passive Stereo Graphics for Collaborative Display of Ocean Model Output

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Principal Investigator: **Phyllis J. Stabeno**

Line Organization: OAR/PMEL
Routing Code: R/PMEL
Address:
NOAA/PMEL/OE2
7600 Sand Point Wy NE
Seattle, WA 98115

Phone: (206) 526-6453
Fax: (206) 526-6811
E-mail Address: Phyllis.Stabeno@noaa.gov

Other Investigators:

Albert J. Hermann	Christopher Moore	Nancy Soreide
Albert.J.Hermann@noaa.gov	Christopher.Moore@noaa.gov	Nancy.N.Soreide@noaa.gov

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Phyllis J. Stabeno	Steve Hammond	Cynthia Loitsch	Eddie N. Bernard
Principal Investigator	Division Leader	Program Support Officer	Director
PMEL	OERD/PMEL	PMEL	PMEL

Commodity Passive Stereo Graphics for Collaborative Display of Ocean Model Output

Proposal for FY 2003 HPCC Funding

Prepared by: Phyllis J. Stabeno

Executive Summary:

We propose to utilize modern, commonly available commodity hardware to build a low-cost, passive, stereo-immersive virtual reality visualization system with the functionality of the ImmersaDesk in a small and portable package. The cost is low because it utilizes existing stereo display software in combination with commodity hardware that is readily available off-the-shelf for computer game users. The technology has been successfully deployed in academia, and will fully utilize the software development and knowledge base developed for the ImmersaDesk. The proposed system will allow the immersive experience to be utilized on the scientist's desktop and also to be shared by a wide audience, ***at one-tenth the cost*** of other large-format display systems such as the CAVE and the ImmersaDesk. Through simple web-browser-based stereo viewing software, it will likewise allow remote ***networked collaborative viewing*** of virtual worlds. It addresses feedback from the HPCC panel and from ImmersaDesk users for smaller, more transportable and affordable immersive virtual reality.

This proposal is submitted in response to the HPCC objective to develop "virtual reality and immersive technology applications" as stated in the proposal guidelines, and has two objectives. First, it will provide immediate benefit to users of the Regional Ocean Modeling System (ROMS, a community circulation model) for displaying model results. Secondly, the proposed system will be a NOAA testbed for a 3D immersive virtual reality system that is far more approachable, usable and available than the large format ImmersaDesk.

Problem Statement:

Immersion is a powerful way to visualize data. Immersive 3D visualization of oceanic and atmospheric data offers significant advantages over simple two-dimensional visualization. Modern oceanographic and atmospheric models contain millions of gridpoints and simulated time periods span multiple years. Finer spatial resolution and longer runs are anticipated as computer power, storage capabilities, and the speed on networks all increase. The challenge of visualizing all this output only increases with time. Under previous ESDIM and HPCC support, we have found that the complex structure of three-dimensional scalar fields, and the direction and magnitude of three-dimensional velocity vectors, and complex spatial paths, are more fully and quickly revealed with stereo-immersive techniques. Following are some **examples of situations where immersive visualization offers a distinct advantage**:

1) *Complex circulation fields*. Coastal upwelling and downwelling are inherently three-dimensional phenomena. A parcel of water typically moves simultaneously towards and along the shore (strong, steady cross-shelf and alongshelf motion), is upwelled (strong vertical motion, highly variable in space), and may become entrained in an eddy (strong but irregular motion in three dimensions, highly variable in space). The superposition of these motions is difficult to capture with any single two-dimensional plot. We have found that animated 3D renderings of velocity vectors and isosurfaces are the fastest way to reveal the evolution of such a complex fluid.

2) *Patchy scalar distributions*. While some of the variables in typical oceanographic models have relatively smooth and monotonic profiles with depth, others have highly irregular distributions which fluctuate strongly through time. Properties subject to strong topographic influence, time-variable forcing, and strongly nonlinear dynamics (e.g. intensity of turbulent mixing, concentrations of phytoplankton or larvae), may develop patchy distributions which are difficult to render fully in two dimensions. Consider how little a simple 2D contour plot of atmospheric cloud cover reveals about the complex topography (let alone the altitude) of individual clouds; this is equally true with "clouds" of high phytoplankton density in the oceans. As model resolution increases, such complicated topographies become more prevalent in model output. 3D techniques are required to allow the fullest exploration of such features.

3) *Complicated spatial paths*. Complex 3D velocities yield complex trajectories of water parcels. and self-directed motions of otherwise planktonic organisms (e.g. vertical migration of fish larvae in response to light) can yield even further convoluted spatial paths. While some two-dimensional techniques exist for revealing 3D paths on a flat sheet of paper (e.g. plot the horizontal path, colored according to depth), the effect is far more vivid when rendered with immersive 3D. Consider how much easier it is to follow the path of a housefly in 3D with binocular vision, as opposed to a two-dimensional plot of the same motion!

Cheaper and easier is the key to wider acceptance. We believe that immersive approaches have thus far not gained wider currency in the scientific community due to factors of cost and ease of use. Under past HPCC and ESDIM support, we have made significant advances in bringing these capabilities to the desktop of the average scientist, who does not generally have access to high-end (expensive) visualization hardware (see http://www.pmel.noaa.gov/~hermann/vrml/stereo.html). Some of these techniques entail rendering greyscale VRML worlds for inexpensive viewing with passive red/blue anaglyph glasses. Other approaches, amenable to a much wider range of 3D software (most notably vis5D and CAVE5D) require the use of stereo shutterglasses for immersion in color virtual worlds. Shutterglasses can in fact be used with an ever-growing number of PC graphics cards developed for the huge gamers market (including any of nVidia's popular GeForce line). However, the need for shutterglasses limits presentation to a small audience, and limits the value of the software as a collaborative tool (as most scientific groups do not have access to IDesks and CAVES, or the expertise to operate them).

The issue here is how to bring the color, immersive experience to a wider audience, in a way that is inexpensive, portable, and more fully interactive. Further, we seek a method which allows for collaborative immersion with scientists who may or may not individually possess hardware beyond a simple PC. An approach based on simple web browsers seems ideally suited to this aim.

The proposed work fits within the theme of Technologies for Collaboration, Visualization, or Analysis. It would provide a tool which could be easily (and inexpensively!) replicated at other oceanographic/atmospheric laboratories.

Proposed Solution:

We propose to build a low-cost (~$25K), passive, stereo-immersive system for display of ocean model output to a large audience. Effective stereo display techniques may be active or passive. Active techniques require the use of shutterglasses, which, in synchronization with a CRT, alternately display the proper (left/right) view to the proper eye (note: the sequential display of left/right frames is commonly called *frame flipping*). Passive techniques display both views at once, but coded differently by color or polarization. Passive lenses worn by the viewer then filter the signal, sending the correct view to each eye. Active techniques have traditionally been very expensive for large group situations. Recent technological developments have made passive approaches very competitive, through the use of dual projector systems. Here, we propose to implement such a dual-projector system, but one which is specifically backwards-compatible with our existing stereo software and the computers which host that software.

The proposed system (Fig. 1) consists of several components: 1) A PC, Macintosh, or unix workstation which supports frame-flipped stereo rendering of 3D worlds. *Many commodity PCs now shipping already have this capability*. 2) A converter/splitter (more properly known as a demultiplexer) to separate the left and right frames into separate digital signals. 3) A pair of DLP projectors which display the two images onto the same screen. 4) A pair of passive filters to polarize the two images differently. 5) A projection screen which preserves the polarization. 6) passive polarized glasses worn by the viewers, to deliver the proper view to each eye.

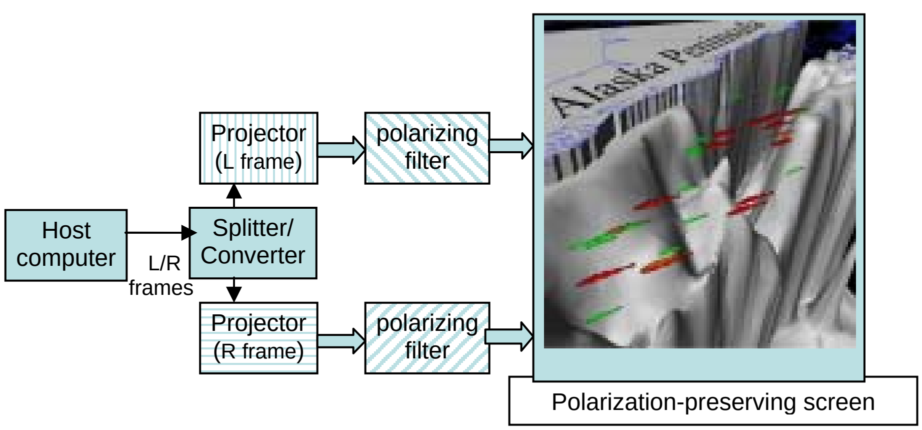

Fig. 1 Schematic of host computer (commodity PC or workstation), splitter/converter, projectors, filters, and projection screen. Thick arrows denote light path.

The entire system is lightweight (under 80 lbs.), small, portable enough for convenient air travel, and easily set up in classrooms and seminars. It can be built (or purchased as a kit) using commodity components. Alternatively, the projectors may be ceiling mounted for fixed use. Systems of this type are in use at over a dozen other educational institutions (e.g. the Geowall consortium; http://geowall.geo.lsa.umich.edu/indexmain.html).

Over the past several years at PMEL, we have developed software tools for immersive stereographic display of ocean model output on a variety of shutterglass-based systems: on desktop/laptop PCs through the world wide web, on unix workstations, and on large format systems such as the IDesk. Packages used include vis5D, CAVE5D, and VRML viewers. VRML clients which support stereo viewing are available for free, as an enhancement to web browsers (e.g. the Cortona viewer, a simple browser plug-in). The Cortona VRML client, in particular, is also amenable to collaborative use by users in different locations, via the web. In this mode, the same VRML world is downloaded to each PC, and information about the current viewpoint is shared by each of the participants. Effectively, they are all viewing the same virtual world from the same location in that world. A simple telephone conference call completes the shared experience; *no other hardware is required*.

Through use of the converter/splitter, the proposed system is fully compatible with our legacy software, and with the video output from our existing computer hardware. Indeed, *any* software or API (DirectX or OpenGL) which can generate a frame-flipped stereo image is usable with this system. Two projectors are driven instead of a single monitor or IDesk, and shutterglasses are replaced by passive lenses. Input devices used for applications like CAVE5D can be physically mounted as part of the system, and ancillary software (e.g. the Flock of Birds positioning system) run as necessary on connected PCs. Hence any stereo-ready software, from games through advanced VR applications, can be run on this passive stereo system.

In addition to using legacy software, we propose to add stereo capabilities to a modern, JAVA-based 3D viewer toolkit (visAD), for use with the new display system. The visAD toolkit was designed for the development of visualization and collaborative tools for earth science datasets. Some existing packages based on this library (e.g. Unidata's Integrated Data Viewer) support interactive isosurface and velocity vector rendering, and accept datafiles already stored in vis5D format. By adding stereo capabilities to the Integrated Data Viewer, we will expand its value for immersive, collaborative viewing of data.

Other software, in development by members of the Geowall community, is directed towards use of the passive stereo display system as a component of an Access Grid node. Much of this software is being developed for Linux systems which include a graphics card supporting two monitors, obviating the need for a splitter/converter. We will equip a PC with Linux and the appropriate graphics card, as an alternate platform for driving the passive display unit, to take advantage of these new developments.

This system will benefit the community of Regional Ocean Modeling System (ROMS) users, with added benefit to PMEL and other NOAA laboratories. ROMS has a large and expanding user's group which can take advantage of the enhanced visualization capabilities. We and our colleagues have implemented ROMS on the massively parallel cluster at NOAA's Forecast Systems Laboratory (FSL), with generous assistance from their staff. The proposed work will leverage a separate proposal to HPCC from FSL staff (T. Henderson et al.) for a TeraGrid implementation of ROMS and a coupled atmospheric model. The passive display system will provide an efficient and inexpensive method of sophisticated remote, collaborative visualization of coupled model output from the TeraGrid.

Several scientific programs now in progress will also benefit from the proposed work. A three-dimensional individual-based pollock model developed through collaborations among NMFS and PMEL scientists (S. Hinckley et. al) has already benefited from immersive visualization techniques developed under earlier support. Animations of fish life histories in three dimensions have been especially instructive, with vertical migration, horizontal dispersion, and entrapment in eddies all clearly visible. More recently, under NOAA/NSF Global Ocean Ecosystem Dynamics (GLOBEC) support, we are developing and running a suite of nested 3D models of circulation, lower trophic level (NPZ) dynamics, and salmon life history in the North Pacific. Multiyear output from these models is being routinely visualized in stereo on shutterglass-based hardware at PMEL. We will implement the proposed passive visualization techniques for this output, and utilize the collaborative tools for interaction with our GLOBEC colleagues.

Analysis:

The rationale for the proposed solution is that it is *low cost* and *backwards compatible* with existing harware and software. The proposed solution will allow the immersive experience to be shared by a wide audience, ***at one-tenth the cost*** of other large-format display systems (e.g. CAVE, IDesk). Through simple web-browser-based stereo viewing software, it will likewise allow remote ***collaborative viewing*** of virtual worlds with other users who may or may not possess any special immersive hardware. This work will lead to ***improved visualization of model output***, and hence a deeper understanding of modeled phenomena. It will bring NOAA technology into the expanding Geowall and Access Grid testbed community. Our experience will be advertised widely within NOAA via web pages. The proposed work efficiently leverages existing Idesk and other visualization skills, FOCI programmatic funding, and several other scientific programs.

Performance Measures:

We would consider this project successful if it enables us to present immersive seminars to a large group, encourages other laboratories to acquire the inexpensive immersive hardware, and results in collaborative viewing of our model output with other colleagues.

Milestones

Month 01 - research and order hardware
Month 03 - configure and deploy new hardware with existing PCs and workstations
Month 06 - add stereo features to visAD-based visualization tool
Month 09 - implement web-based tool for collaborative viewing of VRML worlds.
Month 12 - develop web pages describing our experience; deploy system at conferences

Deliverables

- Web pages describing our experience
- Stereo enhancement to visualization package based on visAD
- Collaborative enhancement to web-based VRML viewer
- Portable stereo projection system for use by this laboratory