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A Stereographic Visualization Environment And Its Applications*

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A Theatre for Collaborative Applications

The data visualization activity at Brookhaven National Laboratory is rooted in programs extending back several decades to develop, evaluate and deploy imaging instruments. Several of these developments, such as Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) technology, were targeted for medical imaging. Other applications made use of images derived from larger, general purpose scientific instruments such as the Laboratory's nuclear reactors and particle accelerators. The most recent impetus to the program has been from a cooperative research and development project between BNL and two industrial companies, GTE and Mobil Oil involving microtomographic imaging of oil reservoir rock, which included development of a novel stereoscopic visualization theatre. This 'Vis Theatre' has been subsequently used for research in other scientific disciplines, and has attracted considerable attention in both the technical literature and even the popular press. [1,2,3]

The Vis Theatre uses a stereographic projection facility inspired by a viewing system developed by GTE for battlefield management studies for the Department of Defense. It projects its three-dimensional images into a conference room setting, using polarized light for stereo separation. The viewers wear passive polarized glasses to see the stereo effect. The 3D illusion created by stereo is enhanced by one or more other visualization techniques including shading, perspective, and motion.

Several design choices were taken to make the facility as useful to collaborative teams as possible. Use of passive glasses rather than expensive, shutter-based mechanisms, exclusion of head-tracking devices which create a 'preferred' user, and location in an actual conference room all invite the possibility of multi-viewer interaction. The facility has also been designed to be easily replicable and its components are network-based, encouraging proliferation and raising the possibility of 3D videoconferencing as well.

The configuration is outlined in Figure 1. Two identical video projectors featuring high intensity and resolution, and fitted with polarizing filters, project onto an 8'x10' back-projection screen specially designed to retain light polarization. The display system is driven by a Silicon Graphics Onyx 2 system. Among the application tools currently used are the Silicon Graphics Performer API and IBM Visualization Data Explorer. There is

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some custom software to perform the stereo separation and effect the image manipulation controls.

Computed Microtomography

The problem posed in the collaboration with Mobil was to provide an accurate image of the interior of reservoir rocks, that is, rock samples from areas suspected to contain trapped hydrocarbons. Not only was the content of the rock of interest, but also the structure of its pores, so an economic decision could be made by company researchers as to whether or not the area represented a good prospect for extracting oil or gas. The Brookhaven National Synchrotron Light Source (NSLS) provided a particularly good source of high-intensity x-rays to make high-resolution microtomographs, achieving spatial resolutions down to 2 micrometers.

To produce such an image, data is collected at an NSLS experimental area, called a Beam Line. The x-rays are passed through the sample, which is rotated to traverse 180 degrees. The resultant one-dimensional projection 'shadows' are passed through an optical instrument to a charge-coupled detector camera, and the raw data stored in a local computer. As shown in Figure 1, from there the data is filtered, the tomographic slices are made, a 3D image is rendered, and in the final step, the dual-view stereo separation and projection is performed. With the current instrumentation, one can acquire data at the 2-micron resolution over a field of view of 3 mm in 1.5 hours. [4] Larger fields of view can be obtained at proportionally lower resolution in the same amount of time. The microtomography processing is trivially parallelizable (one slice per processor) on an array of inexpensive commodity processors, while the 3D rendering and stereography is performed on the SGI Onyx. Processing speeds vary widely with the complexity of the data, but in general, the computing manages to keep up with the data taking activity.

There were several mathematical problems that had to be solved along the way to achieve such efficient processing, where high-resolution imaging creates potentially intractable data set sizes. The first was to find a way to perform partial volume sampling without ruining the mathematical validity of the tomography algorithms. The second was to apply a Fourier transform approach to reduce the cubic growth in complexity normally expected from analyzing 3D images with conventional filtered back-projection approaches. Both these problems were solved to the satisfaction of the applications under study. [5]

Given the multi-disciplinary nature of BNL, it was inevitable that there would be researchers with other scientific problems that would find use for this facility. It has been subsequently used for imaging samples to explore the interior of volcanic lava and meteorites. It has also been used to demonstrate flaws created by impurities in sheet metal, which is of interest to the aircraft industry. In one of the more unusual applications, it has been used to image the interior of a beetle that was implicated in transporting a fungus that has been denuding forests of its trees. This list of diverse applications is expected to continue to grow.

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Biomedical Imaging

It was anticipated that any interest shown by the scientific community in this facility would revolve around the rather unique capabilities of the NSLS to make high-resolution microtomographs. The Visualization Theatre would be regarded as a useful ancillary capability that drew on long-established techniques for establishing depth perception. We were surprised, therefore, when a considerable number of applications developed for using the theatre alone. Several of these applications have arisen in the area of biomedical imaging, which are briefly described below.

Boron Neutron Capture Therapy (BNCT) is an experimental radiotherapy for treating intractable malignancies. It requires treatment planning procedures designed to predict the dose delivered to the cancerous and normal tissues. The problem of course is to maximize the dose to the malignancy while minimizing the harm to the surrounding healthy tissues, which is in this case the brain. Here, depth perception is of obvious great advantage. The technique uses three-dimensional correlation of segmented MRI volumes with 3D Monte Carlo radiation transport calculations of the differential dose distributions produced by neutron irradiation. [6]

Positron Emission Tomography (PET) images have been used to document the real-time evolution of the drug cocaine in the human brain. A study using several dozen subjects established that the 'high' experienced by drug abusers is produced when the cocaine molecule blocks dopamine re-uptake channels in the axons of the basal ganglia. Stereographic animations of this progression were projected in the Vis Theatre. Subsequently, treatments have been postulated that use currently available seizure medication, and these have been shown to be effective in animal studies. [7]

Structural biology examples have been drawn from the Protein Data Bank, a repository of protein structures residing at BNL that is accessible to researchers internationally via the World Wide Web. For example, the structure of Acetycholinesterase, shown being viewed in Figure 2, was first determined at the Brookhaven NSLS. It is the target of experimental drugs designed to alleviate the symptoms of Alzheimer's disease. [8]

Simulations and VR

Whereas the applications described above are broadly in the data visualization area, that is, images derived from experimental data describing existing structures, there is another entire category of images that represent entities that do not physically exist. This is the realm of simulations and virtual reality applications. One of the most common applications of that type is Computer Aided Design and Manufacture (CADCAM) imaging. And indeed, the Vis Theatre has been used for mechanical CADCAM work. The most notable example has been displaying a huge scientific instrument being built for Brookhaven's 'next generation' particle accelerator, called the Relativistic Heavy Ion

Collider (RHIC). This detector contains such inconvenient components as a 40' long superconducting magnet, as well as many very small precision fabricated parts, all fitted tightly into a large room-sized structure. Clearly, this a case where one must get the structure rather fully and properly designed before committing it to construction. And this is where a realistic 3D rendering that can be analyzed by the designers prior to fabrication is extremely valuable.

The actual physics that will be performed by RHIC can be conceptually previewed with simulations as well. Particle collision interactions have been computer simulated, and the results have been projected stereographically both to debug the simulator code and to provide viewers with some notion of the complexity of the interactions. Time-step animations of RHIC collisions depict the emergence of a quark-gluon plasma of particles, some not existing since the 'big bang' creation of the universe.

The phenomena that will be studied at RHIC are related to a computational effort to calculate the properties of strongly interacting particles like the quarks and gluons at high temperature as well as the the masses of known and unknown particles at zero temperature. To perform these calculations, a 12,288-node, 0.6 Teraflop machine is now being constructed at the RIKEN/Brookhaven Research Center. The processors in this computer are interconnected as a four-dimensional mesh with nearest neighbor connections. The data collected is also four-dimensional, representing field distributions on a 64x48x48x48 space-time lattice. To visualize this, a special application was written that views the four-dimensional hypercube as four stereoscopic three-dimensional projections and uses six four-dimensional rotations to inspect all the data. [9,10]

Virtual reality represents yet another category of applications, which BNL staff are just beginning to explore, particularly for studies in the area of national security. A replication of the Vis Theatre has been proposed for training personnel in a nuclear non-proliferation program. This facility can serve not only to place the trainee in a virtual space where inspection and interdiction work can be practiced, it can also project with great accuracy the images and detector signals which should arouse suspicion, and differentiate them from those that are harmless. Similarly, a proposed training program in Crisis Management would use the facility to create a realistic 'war room' for playing out training dramatizations of incidents, and combine it with visual metrics that illustrate the consequences of decisions the trainee takes to manage the incident.

Distance Education

BNL, like so many of the National Laboratories, has also long had a vibrant education program reaching out to faculty and students at every academic level. Recently, staff at Brookhaven and several colleges have been exploring the value of applying the visualization methods described above in the technical education setting. Distance learning is already a well-accepted means of enriching the educational experience. Robust visualization techniques extend the promise of a next step in distance delivery, allowing the inclusion of more immersive experiences, such as laboratory courses, distance co-operative education, and the like.

A program has been designed to explore the efficacy of this 'virtual campus' environment. Stereographic visualization is at the very heart of this concept. Each participating institution would construct a low-cost equivalent of the BNL Vis Theatre. Projects would be selected that are inherently visual and pedagogical in nature, yet represent real work within the Brookhaven research agenda. Teams, including students and faculty from several schools, as well as BNL advisors and support staff, would organize during a first phase of the program conducted during the summer months at Brookhaven. When the academic semester starts, the work would continue at a distance, leveraging the teaming that has already taken place during the summer and the exposure to the Vis Theatre and its techniques. [11]

There are a number of unique aspects to the envisioned program, particularly from the standpoint of the educational institutions. First, it has both on-site at BNL and home campus segments. Secondly, it involves both the students and the faculty, who are charged with providing the continuity after the participating students graduate. Finally, it addresses not only the individual students' education, but also their home institutions' computing infrastructure and its courseware. This concept is embodied in a proposal currently before several funding agencies.

Conclusion

It has been clearly demonstrated that, even with an idea as old as stereography, the combination of vibrant images, compelling applications, and a conducive environment can make a fresh impact on the conduct of science. The visualization facility at BNL is growing in importance as new applications are found and improvements are made to the experimental apparatus, the projection systems and the computational capability. Additional information about many of the applications described above are available on the web at www.ccd.bnl.gov/visualization.

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