Medicine Meets Virtual Reality II: Interactive Technology & Healthcare

The Virtual Embryo: VR Applications in Human Developmental Anatomy

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If virtual reality applications in biology and medicine are going to fufill their promise of recreating the subtleties and complexities of biological environments, they must draw from a rich assortment of heterogeneous and highly dense databases containing information about both the structures and functions of the systems to be simulated. This presents a problem for workers in virtual reality, for there are few readily available resources for accurate and detailed data on human biological structure and physiology. Several national-level research initiatives, such as the Visible Human Project and the Human Brain Project, are taking great strides towards creating information resources that can fill this gap. These projects are creating, for the first time, canonical datasets on adult human anatomic topography and topology which will serve as reference datasets for many areas of research into the applications of computer technology to biomedicine. The Visible Embryo project is an attempt to create such information resources for the fields of developmental and molecular biology. It also represents an integrated approach to developing applications of this technology in the areas of image databases, software tools, educational applications, and both basic and clinical sciences. A critical component of this research involves the development of virtual reality applications for research and education in the basic science of human developmental anatomy, as well as surgical simulation tools for practitioners of pediatric medicine.

The term "metacenter" was coined several years ago by Larry Smarr, the Director of the National Center for Supercomputing Applications, to propose network-based computing and information "centers that actually represent transparently coordinated access to widely distributed computational and database resources. Although the user accesses this resource through a single client program running on his/her own personal computer or workstation, the system provides access to a wide variety of supercomputers and data stores that can reside anywhere in the world with a high-speed Internet connection.

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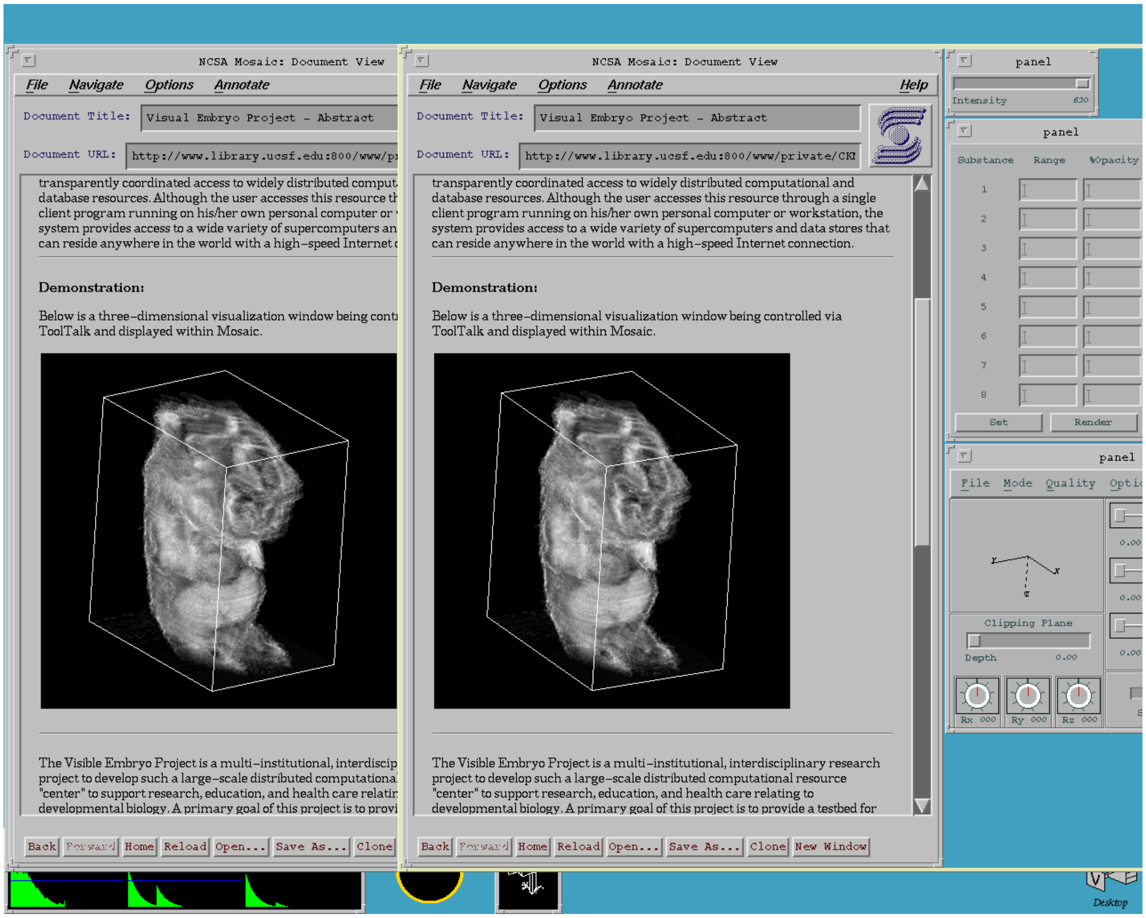
The Visible Embryo Project is a multi-institutional, interdisciplinary research project to develop such a large-scale distributed computational resource "center" to support research, education, and health care relating to developmental biology. A primary goal of this project is to provide a testbed for the development of new technologies, and the refinement of existing ones, for the application of high-speed, high-performance computing and communications to current problems in biomedical science.

Sets of serial microscopic cross-sections through human embryos, within the collection of the National Museum of Health and Medicine, will be digitized and processed to create volumetric reconstructions of normal human embryonic anatomy. During the five years of this initial project, the entire contents of the Museum's Carnegie Collection of Human Embryology, over 600 embryos, will be digitized, reconstructed and archived, together with case histories, scientific articles, research notes, didactic descriptions, and other data contained within the collection. This massive database will be housed at the Museum at Washington D.C., while teams of researchers at more than 20 universities and companies around the United States will access widely distributed super computing resources to develop visualization, analysis and telecollaboration software tools, educational materials, virtual reality simulations, basic science investigations, and clinical research projects based upon the data contained within the collection.

This project will serve the dual purpose of providing a testbed for new technology development in high performance computing and communications, as well as creating powerful new tools for the developmental biology research community. New advances in visualization technology are beginning to allow investigators to break through previous technical limitations and discover universally-applicable rules for pattern formation and shape development in organisms. By applying these new technologies to the existing archives of cross-sectional image information that exist in the literature and in collections around the world, we can tap into an enormous amount of new information that can be extracted from these databases.



This image illustrates UCSF's integration of Mosaic documents with remote access to real-time interactive volume visualization tools. The two embryo images are slightly rotated to form a stereo-pair image which can be viewed in 3D by allowing your eyes to diverge slightly so that three images apear, and then focusing in on the middle image (it takes practice). The interactive visualization controls are to the right.

The task of integrating access to such massive information and computational resources is nontrivial. Just one embryo from the 650 serially-sectioned specimens in the collection can yield as much as a terabyte of anatomical volume data (a 20mm specimen, sectioned at 5 microns and digitized at a resolution of 8000x8000 pixels/section at 36bits RGB produces 1.073 TB of voxel data). It is clear that no single workstation, or even supercomputer, can manipulate, process and analyze such a large quantity of data as a single unit, much less perform computational operations on a database of hundreds of such datasets. For this reason, the Visible Embryo team at UCSF has developed tools to allow integrated Internet access (through NCSA Mosaic) to remote volume visualization engines which can distribute computation across a large number of graphics supercomputers connected by high-speed networking. This allows the integration, through NCSA Mosaic and the World Wide Web, of text-based, image, audio, and video data with real-time interactive control of high-performance visualizations embedded within Mosaic documents. We are also exploring the potential of using this technology for delivering interactive access to virtual reality applications through the Internet. The success of these efforts will allow widespread access to highly accurate and complex virtual reality simulations of human developmental anatomy, using inexpensive workstations and personal computers.