REMOTE CONTROL AND VISUALIZATION OF SCANNING PROBE MICROSCOPES VIA WEB

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Abstract - Our efforts in bringing the Scanning Probe Microscope (SPM) live data available on the Web have been successful. This work is being pursued under the aegis of the IN-VSEE project targeted to bring SPM data live to community colleges, high school and other research labs/classrooms. We have further advanced this to provide the capability of remote operation of the SPM via the web. The truly remote operator can control many functions of the microscope with reasonable security and ease. The latter marks a milestone in use of the Web for truly interactive bi-directional communication involving feedback and control of an instrument. The architecture also incorporates an interactive "chat" channel among the observers and the operator(s) and compressed video delivery in separate windows. Further, since the SPM data is inherently 3-Dimensional, a plug-in has also been developed to display the live data as 3-Dimensional model, with support for zoom, pan, rotation, etc.

BACKGROUND OF TELE-MICROSCOPY

Scanning Probe Microscope and TopoMetrix Corp.

Scanning Probe Microscopes (SPM), such as scanning tunneling microscopes (STM) and atomic-force microscopes (AFM), do not produce 2D images like optical microscopes. They use a very sharp tip to probe the surface of a sample being studied. The tip can be positioned very precisely (within the radius of an

atom), and reports the height at its current position. The tip scans across the surface in a raster pattern, producing a 2D array of heights and other measured properties. TopoMetrix Corp., the first SPM company to broadly license the SPM patents, provides software (Viewer and Control Interface) running on Windows 3.1 which does not support network and multi-users.

NanoManipulator of UNC

Russell Taylor's NanoManipulator (nM) [1,2] project group at University of North Carolina at Chapel Hill has been working with TopoMetrix Corp. for some time. They have obtained software and permission to put code hooks into TopoMetrix software such that the microscope data can be delivered to another Unix workstation via a socket connection. It also controls the functionality of the microscope. However it is a single user. Even nM has simplified the interface of SPM operation. Users of nM still need training and they must have the basic knowledge of Unix, X windows.

Other Projects and Products involving Tele-Microscopy

Below are some Tele-Microscopy related projects and products we know. They are categorized based on the medium they used.

Video Camera Systems

In 1996, Bio-Tech Imaging Inc. developed the Automated Remote Research Microscope (ARRM) [3] which is an automated system for reading and analyzing images of microscope using a color video camera system.

In 1997, Bildanalyssystem AB achieved transferring live video and images from the remote microscope over a digital telephone line [4].

In 1997, UAB's Center for Telecommunications Education & Research introduced the TelePath system [5] that provided remote control of a robotic microscope via a TCP/IP network and used real-time video to transmit live pictures.

Screen, Mouse, and Keyboard Mirroring

In 1996, Oak Ridge National Laboratory [8] achieved remote control of a Hitachi HF-2000 electron microscope by using a commercial software package, Timbuktu Pro, for mirroring the screen, mouse and keyboard functionality.

Specially Designed Environment / System / Equipment

In 1992, NCSA, in collaboration with the STM group at the Beckman Institute, developed a software module [9, 10] which allowed remote control of the Scanning Tunneling Microscope from within the commercial software environment - AVS and the multi-person, room-sized, 3D video and audio environment - CAVE.

In 1995, the Scanning Electron Microscope installed at the CSUH microscope laboratory [7] allowed distant education with other remote campuses and other classrooms on the CSUH campus, which employed a broad-band networking system with the capability to transfer audio, video and visual data.

In 1997, the Neurovisualization Lab at the University of Virginia was developing the IRNS system [6] which allows a remote neurosurgeon to control a robotic microscope through the use of a 3-D input device, communicate with the operating room (O/R) team through live audio and video, and view presurgical imagery.

Limitation of Existing Software

From our survey we found the following limitations in the existing software.

- Lack of support for multi-user access;
- Video camera systems for capturing output of microscope (image) can not provide raw data from microscope, such as height values, for further analysis;
- No provision for viewing 3D models without a specialized computer;
- No bi-directional communication for remote control;
- No platform independent solution.

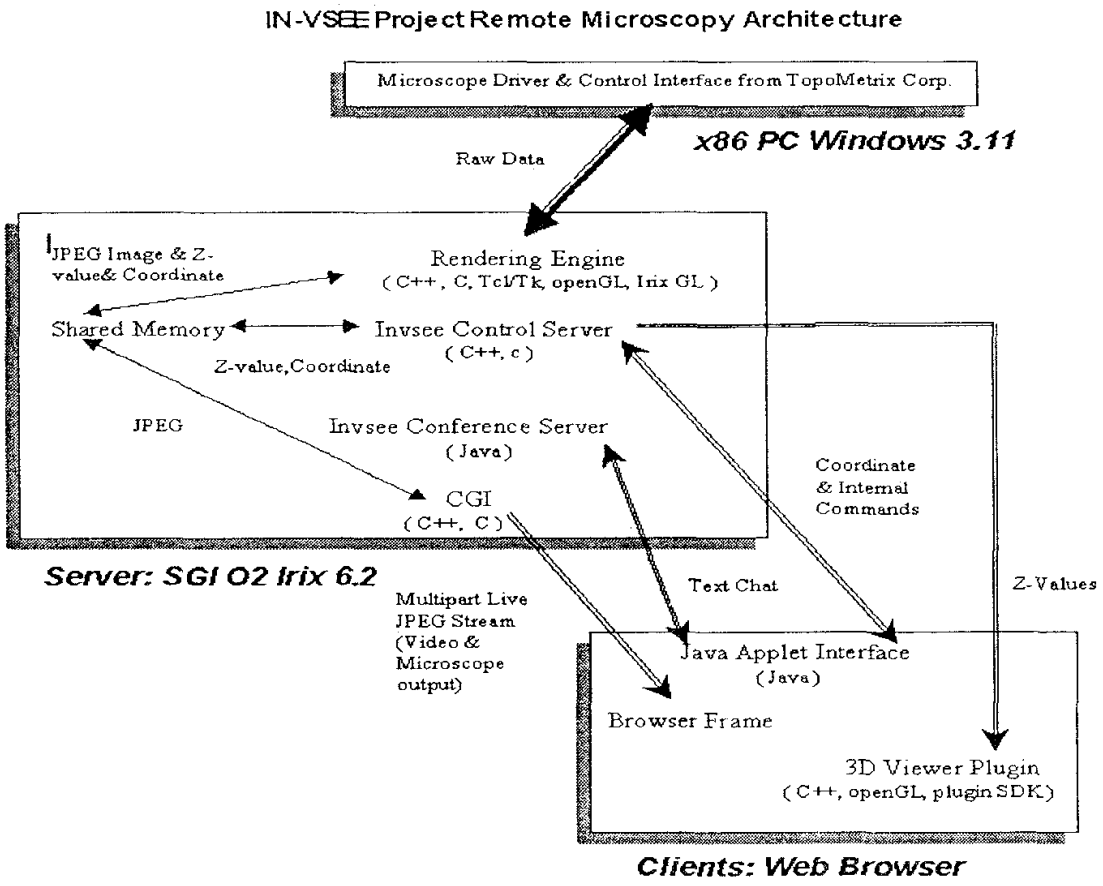
A PLATFORM INDEPENDENT SOLUTION – THE IN-VSEE SYSTEM

The IN-VSEE Project

The main goal of the IN-VSEE (Interactive Nano-Visualization in Science and Engineering Education http://invsee.asu.edu) project is to design and implement a live data broadcasting and remote control system for the Scanning Probe Microscope. The system allows one or more users to remotely view and control a microscope connected to Intranet or Internet. This project makes the microscope facility sharable through network and increases collaboration between researchers. It's also a goal to improve efficiency of online education and distributed design.

IN-VSEE Architecture Design

Development of World Wide Web (platform independent) capability is key to the success of the IN-VSEE project. The main components of the IN-VSEE system are the Rendering Engine, Conference Server, Control Server, CGI, Java Applet Interface and Plug-in.



The rendering engine, including the low-level remote control interface, is based on the UNC NanoManipulator. We modified the nanoManipulator (nM) server to make it suitable for our application. The SGI machine acts as a gateway for remote microscope operator and handle services requests from Web clients for 2D images and 3D data. The client software runs on Web browser (Netscape 3.0 and higher) which supports HTML 3.0 and Java. We compress rendered images into JPEG pieces and send them as MIME image stream to web browsers directly (Server Push). Since web browsers provide native support for JPEG and MIME type image, no browser plug-in is required for receiving 2D data. We also provide a straightforward remote control interface (Rubber banding Java Applet) and a 3D viewer plug-in for Web browsers. Students and non-experienced users can use it to control a microscope without any training. This interface will in future provide

different levels of functionality based on users proficiency in controlling the microscope.

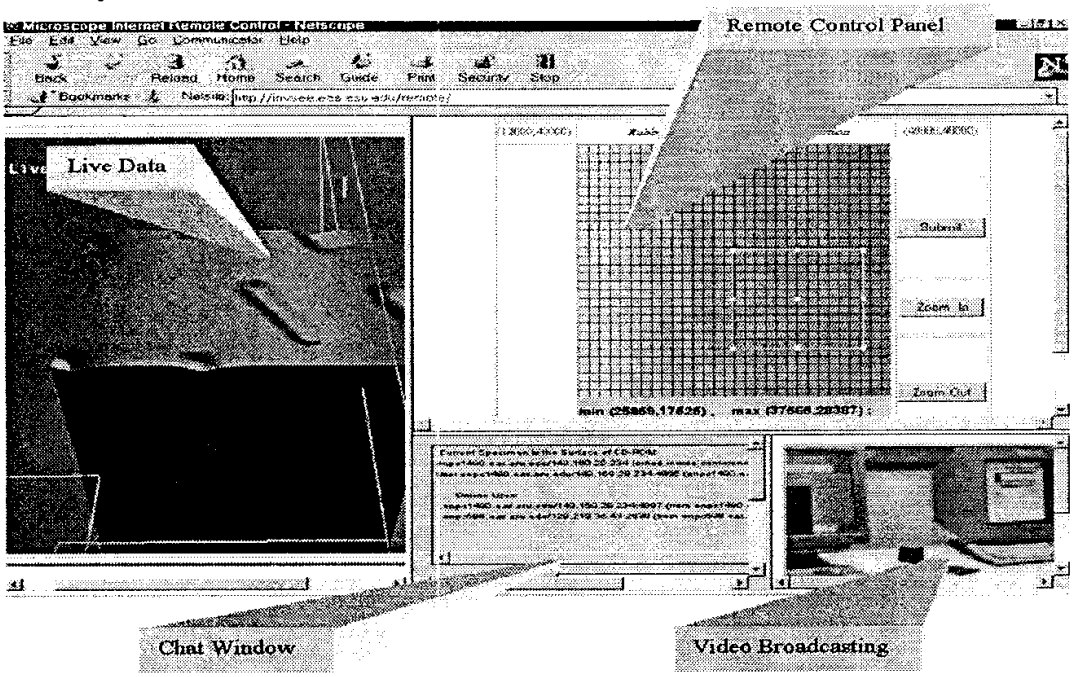


Figure 2: Web browser showing live 2D data of the surface of CD-ROM

CONCLUSION AND FUTURE WORK

Our system is designed to combine experimental, visualization and analysis in an easy-to-use multi-clients environment. Future work and extension to the current system would be in the following areas:

* Replace Microscope with other instruments

* Automate scanning job for Microscope

* Integrate voice sub-system for communication

* Simulate the modification of specimen surface in 3D plug-in so that we don't have to damage the specimen during the experiment

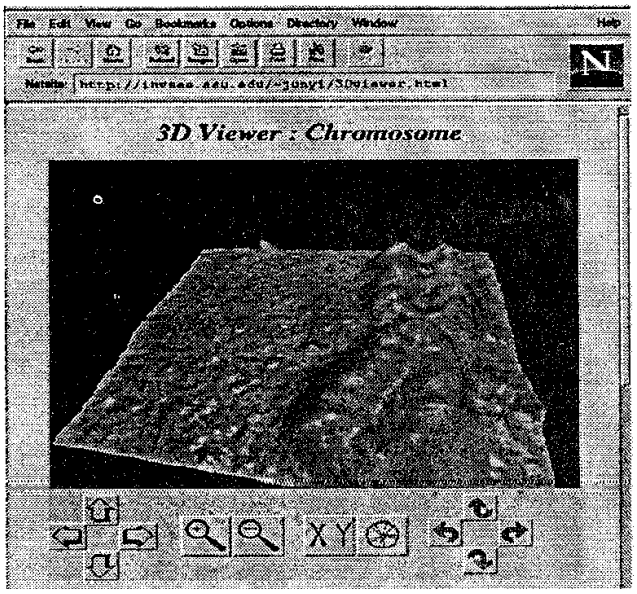


Figure 3: 3D plug-in showing chromosome under mitosis

ACKNOWLEDGMENTS

We would like to acknowledge Russell Taylor's NanoManipulator group at University of North Carolina for supplying the software and providing technical support of their source code. We would like to thank the members of IN-VSEE group, in particular B.L. Ramakrishna and Tony Garcia. This research is sponsored by the National Science Foundation.

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