Tele-Experimentation for Machine Vision Course Using NetMeeting Software

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Motivation For Project

One of the thrusts in the UGA/Biological & Agricultural Engineering Department curriculum is to enhance the experiential learning aspects for our engineering students, by improving and increasing access to a few of our laboratories with more test equipment and stations. When expanding laboratories, it requires sizable investments. Even with additional workstations, at times there are not enough workstations for the increasing student enrollment in certain areas: for example in the "Sensors & Transducers" class for Fall 2000, there were 32 students for 6 fully equipped test stations.

A new course in "Applied Machine Vision" will be offered during the Spring Semester 2002. The objective of the course is to provide a hands-on experience for each student; therefore, students will use spectrometry and video imaging equipment to complete assignments. We estimate the enrollment to be 20 students. To accommodate this class size, we would need about 4-5 complete workstations for each assignment. This approach would require another sizable investment.

Innovative approaches have been adopted to accommodate the number of students in order to provide each student with a hands-on experience. The traditional approach to laboratory exercises required a scheduled lab period during which the class, or part of the class, met with the instructor or lab assistant and completed the exercise. This approach requires a large number of workstations or lab periods to accommodate the enrollment. Second, the time each student spends in lab is limited to the duration of the lab period. In "Sensors and Transducers" laboratory-type homework requiring students to use laboratory equipment to complete the assignment has been used as an alternative to scheduled lab periods. This arrangement increases the time the student has access to the equipment, since the laboratory is open for 14 hours each day. An advantage of this method is the assignments can require students to explore methodologies beyond those presented in lectures.

During the development of the course "Applied Machine Vision", we determined that the laboratory portion would be a major component. However, access to the laboratory during normal operating hours might not be enough for each student to complete the assignments. As we explored alternatives, the following trends/facts were noted:

1) Among the incoming freshmen over the last 2 years, about 90-95% of these students have PCs and Internet access from their residence while going at UGA.
2) With the semester system, the students attended more classes during the day (8AM-5PM), thus usually worked in the lab at night. Therefore, more proctor time was required to keep these labs open at night.
3) Practically all our teaching test stand and apparatuses are accessible and controlled through networked PCs.
4) Our students need to be exposed to state-of-the-art research equipment which usually is too expensive to duplicate and usually not available to students for hands-on practice. However, most of the equipment is accessible through networked PCs.
5) Recently, more PC remote access technologies are available to the common home users such as Microsoft Internet Explorer and NetMeeting.
6) The University's focus is on providing students with easy access to the resources critical within their chosen disciplines.

Considering all six factors, we believe that it is feasible to set up a system so that students can perform their laboratory assignments remotely via the Web, without loosing much of the touch and feel of actual hands-on experimentation. This remote access to experimental apparatus becomes tele-experimentation.

Rationale for Selected Approach

For our "Applied Machine Vision" course, we were designing for a curriculum emphasizing the "pre-imaging" technologies and techniques rather than image-processing techniques as in a traditional computer-science oriented course (which was already being taught at the UGA Department of Computer Science). We were planning to introduce concepts of applied spectrometry in order to later develop into a color vision model as an application of multi-spectral imaging instead as a technology mimicking human color vision. We were also looking into lighting schemes, both structured and non-structured, and also at real-time image acquisition methodologies. Early in the development stage, we realized that we could not adopt the standard mode of laboratory design where groups of 2-3 students would share one machine vision system during a fixed weekly schedule, because it would require at least 4 machine vision stations equipped with needed hardware and software and several lab periods. Therefore, the standard approach would be cost prohibitive. We opted for a 2-station setup. This setup required expanded lab hours and the hiring of a lab proctor. Since the vision hardware and software needed a PC, the obvious solution was to network two PCs and let them be accessible through the web 24 hours/day and 7 days/week. The result is a fully equipped laboratory where the students can perform the lab experiments remotely and at their "conveniences".

Materials and Methods

A quick research into ways for PC remote administration/application sharing resulted in 2 possible "freeware" solutions ("free" so that students can download them as needed on their own PCs). One is based on the ATT Lab VNC [1] (Virtual Network Computing environment), which is more designed for PC remote administration. The other was NetMeeting[2] from Microsoft Corporation, which is designed as video conferencing software, currently capable of sending video and sound to another single PC. NetMeeting also has built-in facilities for chatting and application sharing which can be used in the design of this new way of "doing labs". In the end, we decided to use both software packages in this project: ATT VNC to perform remote administration of the machine vision stations as needed to troubleshoot or reset the computer systems; and NetMeeting to actually share the spectrometry/machine vision application software.

The complete laboratory computer cluster consists of 1 Web/FTP server and 2 PCs set up as machine vision workstations. The Web/FTP server is a Compaq, dual Pentium III @ 866 MHz and 512 MB RAM, running Windows 2000 Server. The workstations have AMD Thunderbird CPUs clocked at 1.2 GHz and 256 MB RAM. Their motherboards have built-in graphics and multimedia peripherals and EIDE disk controller interfaces. These workstations run Windows 2000 Professional. Each system has 5 PCI slots occupied by:

1. An analog video frame grabber from ImageNation (PX610-20).
2. A digital video frame grabber from BitFlow (RoadRunner PCI 12-M).
3. A data acquisition card from National Instruments (PCI-6711) to control various analog/digital input and output lines as needed.
4. A motion controller card from National Instruments (PCI-7344) to control an X-Y stage from Daedal Division of Parker-Hannifin Corporation.
5. Ethernet network card from 3Com (3C905C-TX).
6. A data acquisition card from Ocean Optics (ADC2000PCI) to interface with their spectrometers (it replaced the BitFlow card during the first part of the course).

Figure 1 shows the typical layout for the workstation with the PC, spectrometer and associated fiberoptics, the X-Y stage and a color chart being used for reflectance experiments.

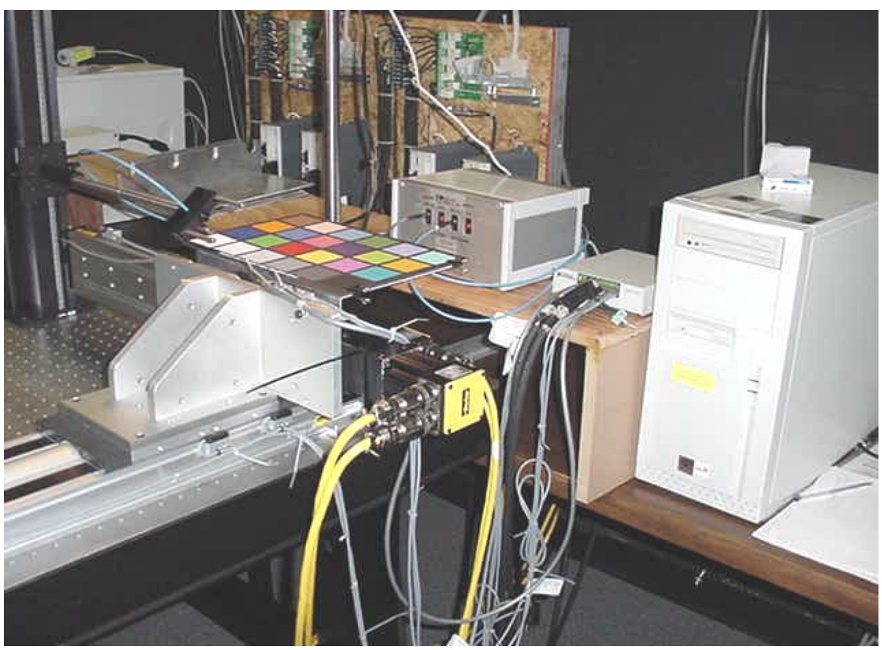

Figure 1. Typical layout for a Machine Vision workstation

Initially, the two workstations must be setup by the administrator prior to accepting any remote logins by students. The administrator first logs on locally at the actual PC or remotely via the Web. For remote administration of the workstations, we used ATT VNC, installed on each machine as a Windows "service". After normal log-on, the OS will "start up" the regular services and "NetMeeting". Next, either the "OOIBase32" (Ocean Optics Corp.) or "QuantIm" (Zedec Technologies Corp.) software package is launched. "OOIBase32" is used to interface with Ocean Optics spectrometers and is needed during the first part of the course while "QuantIm" is used during the later part of the course when video technologies are explored. The last software package to be automatically started is a custom executable LabVIEW [3] Virtual Instrument (VI) named "XY Axis Move". This VI is used to control the motion of the X-Y stage and the power supplies for the equipment used in various experiments. Lastly, the administrator has to "manually" set up NetMeeting to:

1. be a "meeting host".
2. accept all calls "automatically".
3. share the applications "XY Axis Move" and "OOIBase32" or "QuantIm" as appropriate.
4. accept request for "control" of the shared applications "automatically".

We are still searching for a way to automate these 4 last steps and had tried the freeware called "RemoteKeys", but so far we have not been successful. When NetMeeting has been properly setup, the 2 workstations are ready to be accessed via the Web.

Students can access the machine vision workstations from a remote PC through the web server. They must first point their web browser (Internet Explorer 5.5 or above, preferred) to this URL http://weblabs.engr.uga.edu. The "weblabs" server will prompt the students for their user names and passwords, which correspond to local user accounts (set up for each student) on the Web/FTP server (see Figure 2).

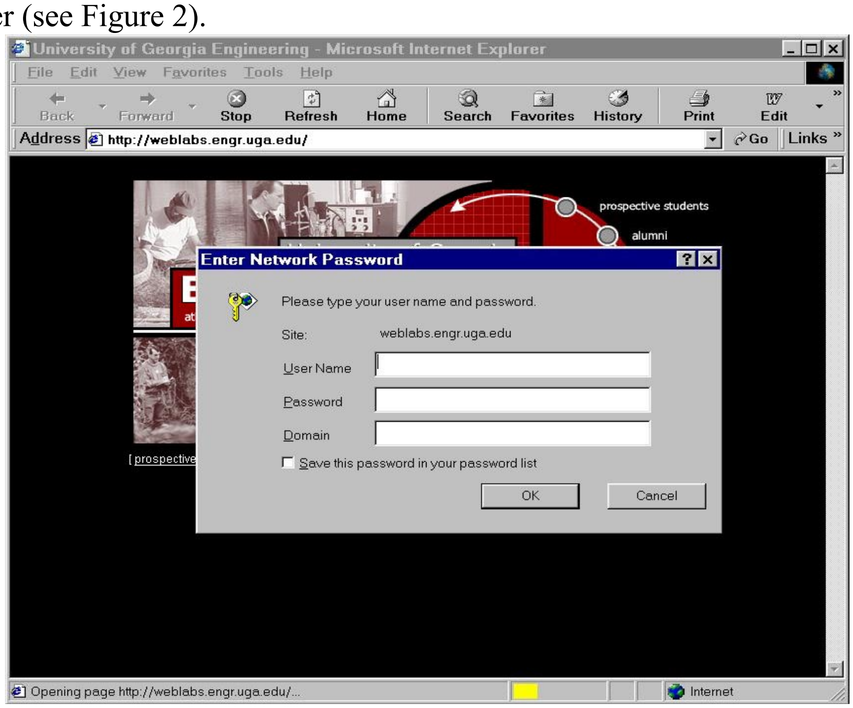

Figure 2. Logging on "weblabs" requires Windows local user name & password

Once the students get to the home page of the server, they can find various tutorials on the use of NetMeeting and other software packages, QuantIm and OOIBase32 (see Figure 3). We plan to put other class and laboratory notes on the university's WebCT server.

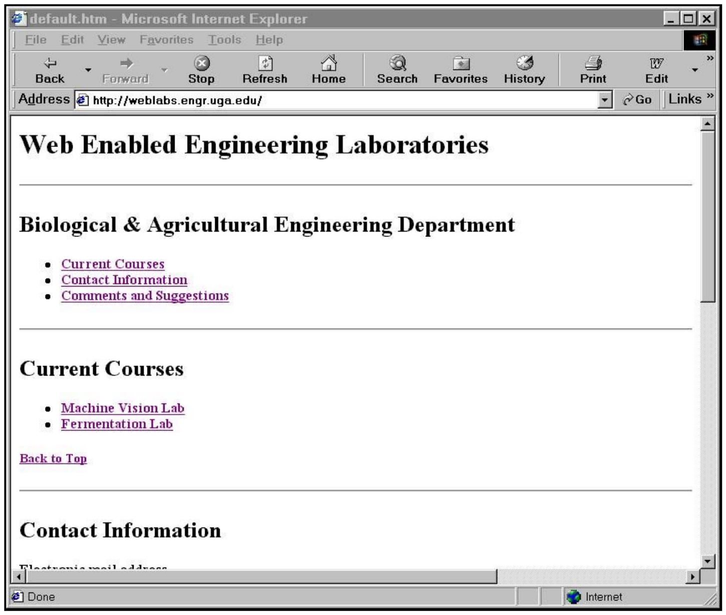

Figure 3. Welcome page to Web Enabled Engineering Laboratories

To work on Machine Vision experiments, they click on the link "Machine Vision Lab", and they are sent to another page wherein they can choose one of two links that will take them to one of the two workstations (see Figure 4).

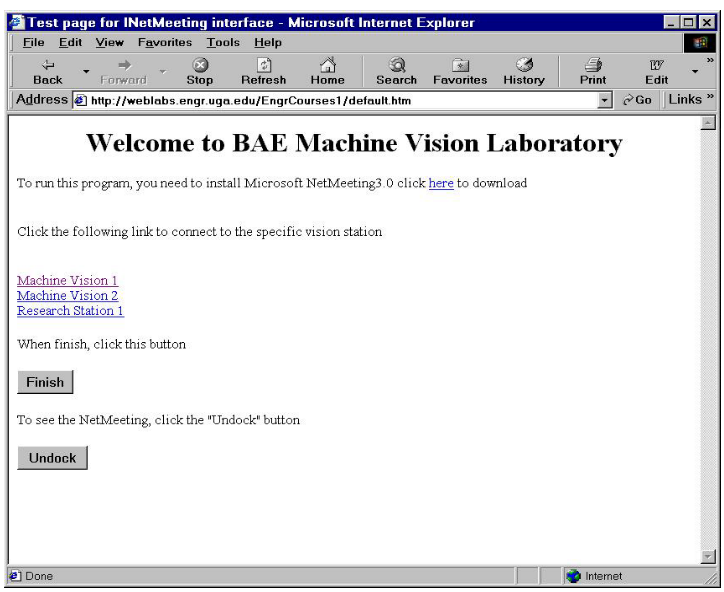

Figure 4. Welcome page to Machine Vision Laboratory

This particular HTML page has embedded Active-X controls that will instruct the NetMeeting software installed on the student PC to "call" the chosen workstation and establish point to point contact with that workstation. If the student clicks on the "Undock" button, the student will see the familiar NetMeeting interface. This interface will prompt the student for a conference password. After some connection preparation time, the student will see the desktop screen of the workstation as shown in Figure 5.

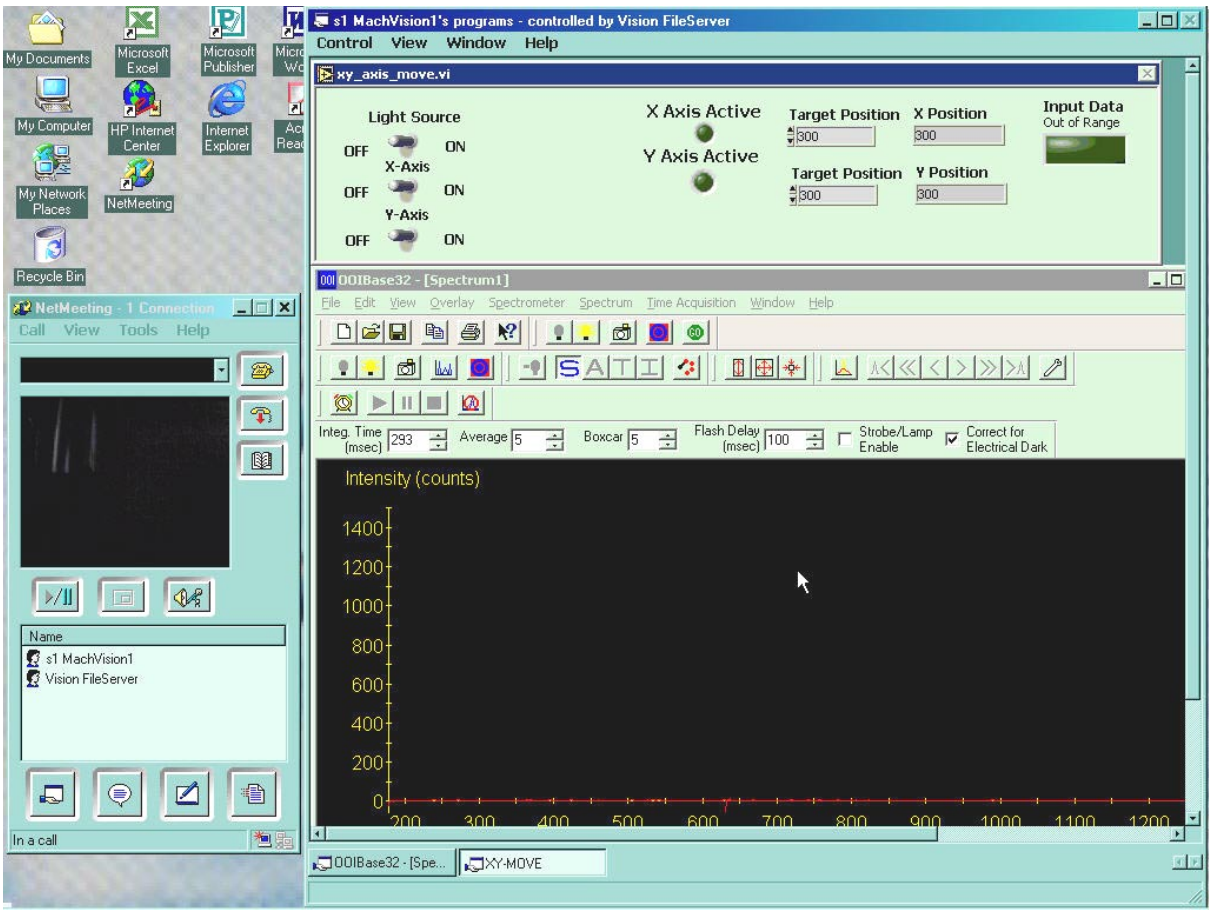

Figure 5. Student computer display when first contact with chosen workstation

In Figure 5, ones can see the familiar NetMeeting 3.01 interface and the windows corresponding to the shared applications "XY Axis Move" and "OOIBase32". But the video image is dark and there is no spectrum shown in the "OOIBase32" window because the light "switch" in the "XY Axis Move" VI is not turned on. Next the student needs to turn on the power to the devices by clicking the 3 toggle switches. When the three switches are in the 'on' state, the light source and power amplifiers for the two translation stages are on. There are some safeguards designed into this VI to prevent some potential problems that can arise such as the light source may be left on with no user activity for a long time or that the X-Y stage may not start up correctly or may not initialize to the "home" positions properly. Thus, as soon as any of 3 switches is clicked ON, a timing clock is started and the student has 20 seconds to finish turning ON the other 2 switches.

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If all 3 switches are not turned on within this 20-second period, all switches are reset back to OFF, and the student has to restart this process. When all switches are turned ON within the prescribed 20-second period, a 4 second delay allows the power amplifiers to complete a power up sequence and then the "INITIALIZE" button becomes visible (see Figure 6). Next, the student has to click on the "INITIALIZE" button as soon as possible, because if this button is not clicked with a time period of 30 seconds as counted from the event when the student turned on the first switch, the whole system will be reset to OFF (i.e. light source OFF and X-Y stage inactive as shown in Figure 5), and the student has to start the whole process all over again.

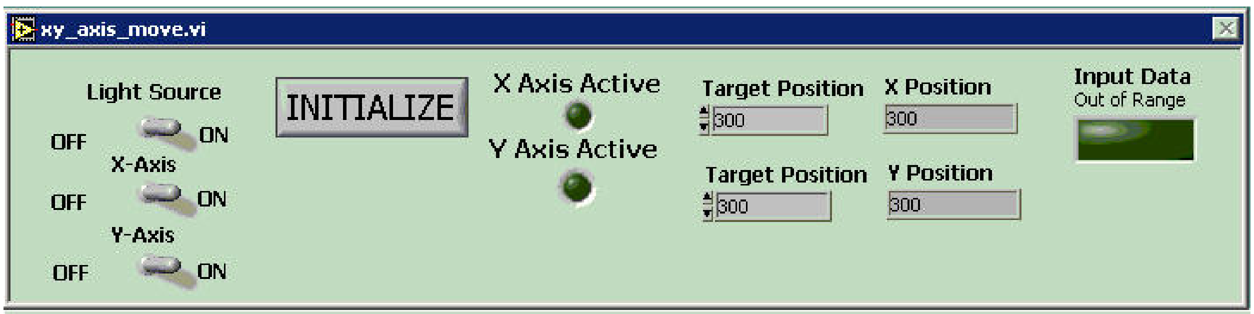

Figure 6. X-Y stage ready to be "initialized"

Once the X-Y stage is initialized, i.e. it is sent to the home positions (0,0) on both axes, the student now sees a display as shown in Figure 7, wherein 2 new buttons become visible ("END" and "GO").

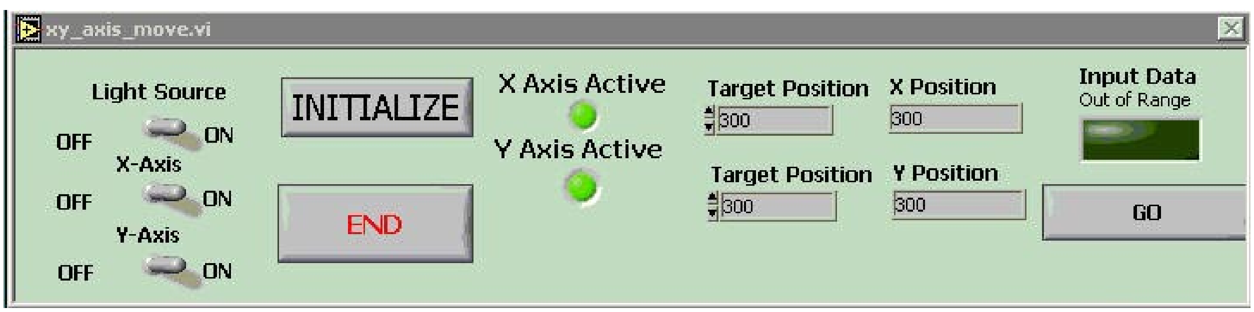

Figure 7. X-Y stage now ready for experimentation

In Figure 7, ones can also notice that the "LEDs" are now colored green, letting the user know that both axes are positioned at the home location and active. Here another safeguard was built-in: if for some reasons, either one of the 2 axes could not reach the home location within 100 seconds since the time the student turned on the first switch, the whole system will be reset to the OFF state as depicted in Figure 5. If all went well, the student can now enter the desired target X & Y positions wanted in the respective data fields and then click "GO". The student can then see the actual positions of the X-Y stage being updated in the respective data fields labeled "X position" and "Y position", as it moves towards the desired location. The student can also visually verify the stage motion and final location via the video feedback through NetMeeting (see Figure 8). During actual experiments, the student will be provided with actual (X, Y) positions to be used for each test sample. The student is ready to collect data.

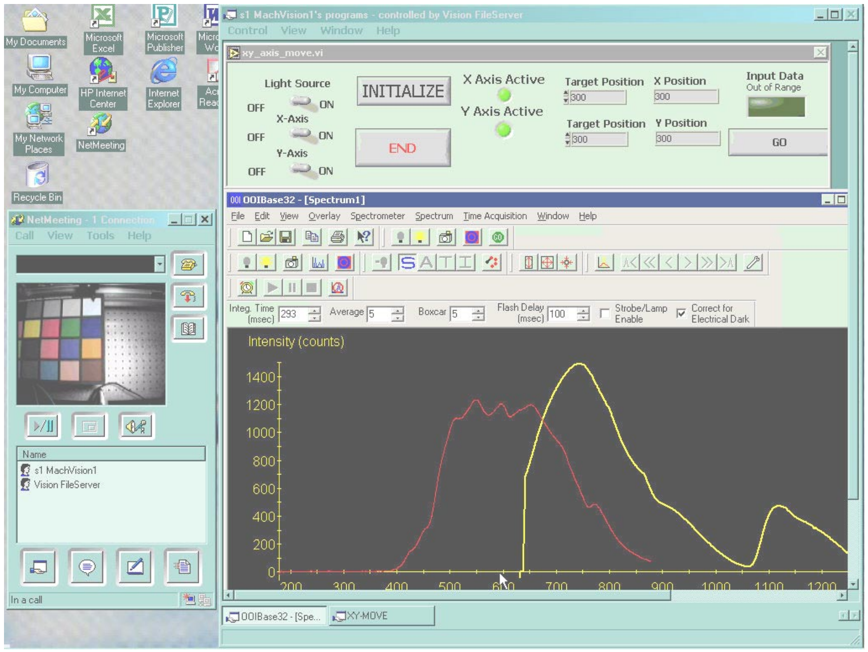

Figure 8. The complete system is now ready to collect data

The student can only save collected data on a drive named “MVData” which is a mapped network drive, actually located on the Web/FTP server. The Windows environment on the machine vision workstations is also preset with a group policy [4, 5] that will not allow the C: drive to be accessible to the student user (along with other security measures). The student also needs to choose the correct folder corresponding to the student name (see Figure 9).

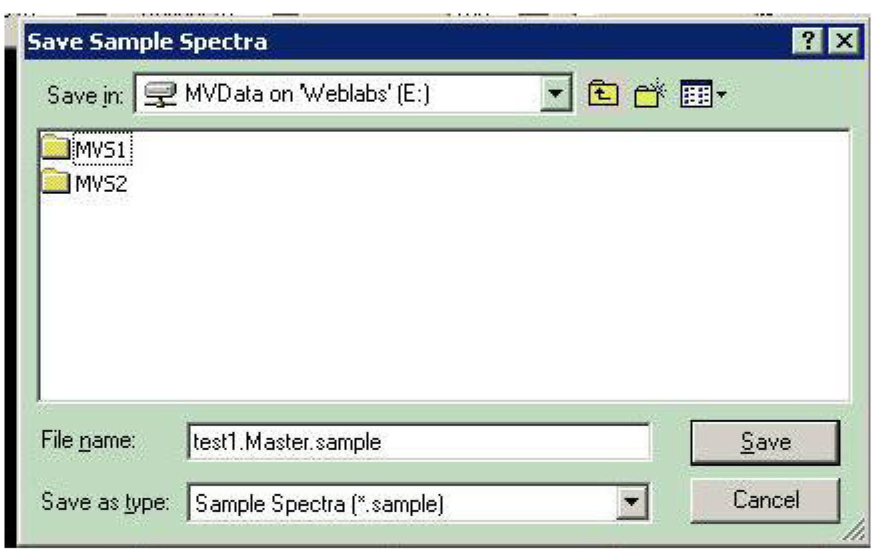

Figure 9. Saving collected data onto “MVData” drive on “Weblabs” server

When done with the assignment, the student can click on the "END" button to turn off the whole system and then disconnect from NetMeeting. Here, a final safeguard was also implemented in the "XY Axis Move" VI: if a time period of 20 minutes had elapsed since the last "GO" command was sent to the X-Y stage, the whole system is automatically reset to the OFF state of Figure 5.

It must be mentioned that request for control of the shared software applications is granted automatically to the student who happens to be the first to connect to the selected machine through NetMeeting. For subsequent users connecting via NetMeeting to the same machine, they can only watch the activities of the first user and exchange communications with the first user via Chat. The second person in line will get control of the machine vision station after the first one logs off NetMeeting.

To retrieve their collected data, the students need to point their web browser to the following FTP site ftp://weblabs.engr.uga.edu. After logging in with personal user name and password, each student is directed only to his or her data folder [6] as shown in Figure 10.

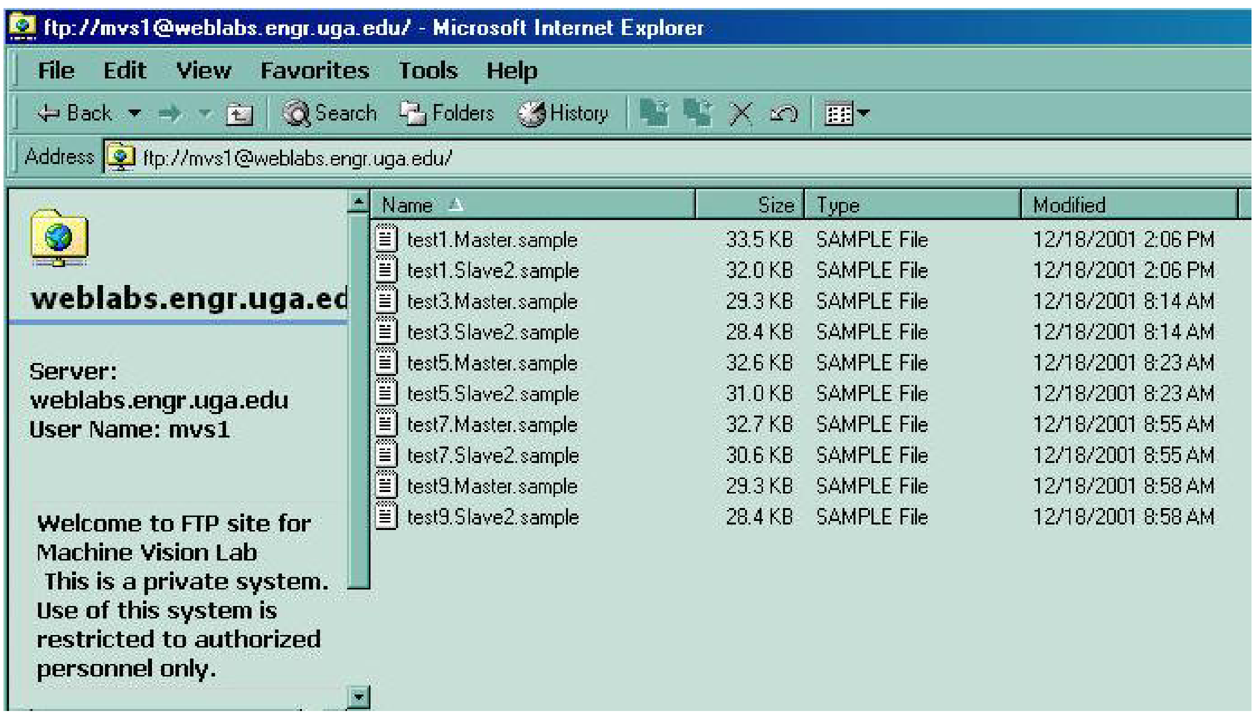

Figure 10. Retrieving data from FTP site

The student can then highlight the wanted files and copy them down to the student PC local drive via the Web.

Discussions

Preliminary testing of this system showed that the system performance was quite good via a 56K modem, at an actual rate of 50K bps through a commercial Internet service provider, and at a location 60 miles away from the UGA/BAE location. However if the connection rate drops to 30K bps, the visual feedback becomes unacceptable and the system is unusable. Notably, in early January 2002, we had a successful connection to the system via the web from Chongnam University in South Korea (it was night time in Georgia, and mid-morning in South Korea).

As there will be "no instructor in the lab" per se, we will need to develop a fairly extensive web based help system for FAQs from the students to help them troubleshoot problems. E-mail will be used to report all system troubles to the instructors. As part of each assignment report, the students will need to include their "control origin" whether it is inside BAE department, on UGA campus or off campus, the number of hours spent for experimentation, and the time of the day when the experiments were performed. With these data and along with actual report grades, we can infer about the usefulness of this approach and whether the remote access feature has created any adverse effect to the learning process of students. Furthermore, the Web/FTP server and both PC workstations are set up to yield fairly detailed access logs.

At this point in time, the issue of potential scheduling conflict among students is recognized, but in the current Phase 1 we will let the students work this matter out for themselves because the number of PCs and students involved is still small. We have arranged so that students can use the calendar feature in WebCT to schedule their own preferred time slots to perform laboratory assignments. In Phase 2, we will use automatic scheduling facilities similar to those of Microsoft Exchange 2000 Conference Server. The "chat" feature of NetMeeting can also be used for communication and collaboration among groups of students if a group effort is required for the assignment. Data security is also another concern to be addressed and we will be using hard disks backup systems so as to bring failed systems back to operational status within a few hours. Lastly, it must be mentioned that this remote configuration is actually similar to the systems that the students will encounter when they graduate and work in industry.

Conclusions

Our Machine Vision course started on January 8, 2002 with 15 students enrolled. At this point in time (mid February 2002), we had performed 3 spectrometry experiments on reflectance and transmission properties, and we had not encountered any serious network malfunction. As of 2/19/02, we will be switching to the video imaging section of the course. In the beginning, when the students tried to log in from work and home, we encountered several issues such as:

1) Outdated or incompatible web browser usage (need to be at least Internet Explorer 5.5 SP2, and Netscape does not work with our system).
2) Firewalls & NAT (Network Address Translation) problems that were resolved eventually.
3) We found that, after 2-3 days of continuous web hosting, the operations of the machine vision stations became sluggish, thus each vision station had to be "restarted" daily, either at the local machine on regular weekdays, and remotely via VNC during the weekend. Occasionally, we had encountered problems during shutdown/restart of the vision stations, at the local machine and remotely, due to certain DLL not unloading properly during shutdown. At this point in time, physical intervention at the local machine was

required to force the machine to restart manually.

4) So far we had no major complaints from the 15 students using the systems. As the students always waited until the last minute to do their labs, we had experienced so far 1 incident triggered by problems described in item 3) above during one Sunday evening, whereas the students could not access one of the vision stations.

We plan to report more fully the results on the system performance and usage at the annual ASEE meeting in Montreal later in the summer of 2002.

The potential application in other courses for the UGA BAE department and in other academic areas is quite extensive, as it may reduce the overall number of equipment needed for teaching and personnel time to proctor laboratories. Furthermore, we can put unique research equipment within the reach of students. And when Phase 2 is activated and assuming that the BAE department obtains its own gigabit Ethernet connections at that time, we will have the capability of having synchronous-collaborative classes with other institutions in the University of Georgia System and the U.S.A. and even overseas if needed.

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BIOGRAPHICAL INFORMATION

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Associate Professor, Biological & Agricultural Engineering Department, University of Georgia. Research interests are in the development of optical sensing systems for stress and disease detection in peanut and cotton plants and for evaluation of quality of agricultural products using standard UV-VIS-NIR spectroscopy and Multi-spectral Imaging, and in the development of distance learning technologies and methodologies.

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