

Pilot Test Results of a New Distance Laboratory Platform

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Abstract

A number of laboratory pedagogies have been developed to support distance learning. The authors' approach has been to develop a hands-on laboratory experience delivered via the Internet using an internally-developed system called ALTE (Automated Laboratory Test Environment). The system consists of a single management server and multiple lab stations, each with dedicated measurement and instrumentation equipment and a PC. At each lab station, a device under test (DUT) is connected to a LabVIEW virtual instrument panel that interfaces with traditional test equipment.

ALTE was pilot tested in fall 2004 in two courses with a combined enrollment of thirty-one students. Both courses were offered by the Electronic & Computer Engineering Technology Department (ECET) and covered analog and digital circuit theory, respectively. During the semester, students in each course performed two experiments over the Internet using ALTE and the remainder of the experiments using the traditional method of coming to the onsite lab. Lab reports were submitted and graded using the same criteria. Comparisons were made between the distance and onsite lab reports and a questionnaire was administered to the students to collect qualitative feedback on their experiences.

Introduction

At the University of Hartford, Engineering and Technology programs have enjoyed a trend of sustained growth. Both graduate and undergraduate programs have experienced increasing enrollments, and as a result, this has severely limited "open-lab" availability. "Open-lab" has traditionally been a time when students can access the laboratory classrooms to finish lab assignments, makeup missed work, and get additional experience with the laboratory instrumentation. Our philosophy in creating ALTE was not to replace the onsite laboratory experience, but rather to supplement it with a system that provided 24x7 access to the same experiments via the Internet.^{[1]-[2]} The aim was to allow users to run experiments nearly identical to the ones that they now perform in onsite laboratory.

Much of the early work that used the Internet to remotely deliver experiments began in 1998 with Esche and Chassapis.^[3] It was followed by a series of work reported in 2000 by both Esche and Gurocak.^{[4]-[6]} Each year, additional work has appeared that has further validated the viability of distance labs and their effectiveness in delivering a worthwhile laboratory experience.^{[7]-[12]} The quality of the architectures and designs of distance labs has steadily improved including the latest presented at the 2003 ASEE National Conference.^{[13]-[19]} There is ample evidence that this

form of experimentation delivers a valuable learning experience for students. Recently, a structured way of comparing distance labs and onsite labs was proposed by Corter et al.^[20]

The ALTE platform was built during the 2003-2004 academic year which included two production lab stations that support the delivery of distance labs to students in electronic courses. ALTE was designed as a robust platform capable of supporting a large number of production lab stations. A pilot test of ALTE was developed and conducted during the fall 2004 semester. The objectives of the pilot test were two-fold: to evaluate the capability of the ALTE platform and to assess distance labs as a supplement to onsite labs.

Automated Laboratory Test Environment (ALTE)

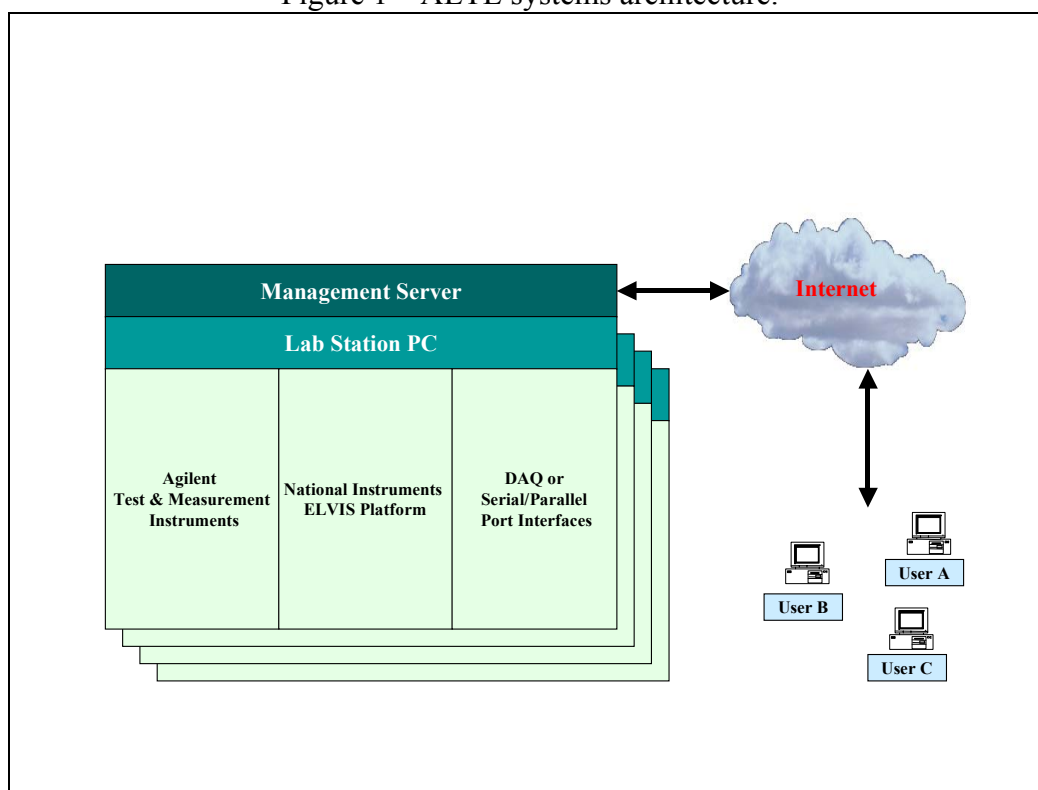
ALTE consists of three elements: a web-based application/database system that manages online access and lab station resources, testing protocols that run on multiple lab station PCs, and hardware/instrumentation that transmit signals and collect data from DUTs. Multiple lab stations, each with a dedicated mix of measurement equipment interface with the DUTs. Lab stations can be equipped with different equipment bundles such as Agilent (i.e. DMM, function generator, oscilloscope), National Instruments' Educational Laboratory Virtual Instrumentation Suite (ELVIS) and custom data acquisition or serial/parallel port interfaces for programmable devices.^{[21]-[22]} At each lab station, the device under test (DUT) is connected to a pre-developed LabVIEW virtual instrument panel (VIP) that is the user interface to perform the experiment.

To facilitate the collection of usage statistics on the ALTE platform, it was designed to automatically track five parameters. These metrics were linked directly to the students who performed the distance labs:

- Courses and experiments on ALTE lab stations.
- Students who performed distance labs
- Connection hours spent on distance labs
- Time of day distance labs were performed

The measurement process was automated using the server as the collection platform. ALTE tracked student access by course, by student id and time-stamped each session. This ensured that data was consistently collected, and also yielded more in depth statistics on the patterns of usage such as time of day, session length and levels of interactivity. Figure 1 shows a high-level view of ALTE's architecture for three different equipment bundles.

Figure 1 – ALTE systems architecture.



NI ELVIS Lab Stations

ALTE can accommodate a variety of test equipment in the underlying lab stations. For the pilot test, two lab stations were equipped with NI ELVIS units. NI ELVIS comes with internal instruments, an interface to LabVIEW and a circuit breadboarding area. The pilot test used the NI ELVIS oscilloscope, function generator, digital bus reader and digital bus writer.

Setting up an ALTE lab station to support a distance lab is a relatively easy process. First, the instructor must write a lab procedure and upload it to ALTE as a Word or PDF document. The lab procedure is very similar to those handed out to students when they come to onsite labs. However, it should also contain a section that describes how to collect data using the virtual instruments of NI ELVIS. Since this was the first time students were to perform a distance lab, we included a detailed section on how to access the labs and operate the virtual instrument controls.

In the second step, the test circuit must be built on an NI ELVIS breadboard and connected to the desired signal inputs and measurement points. The connections are well labeled so the test circuit can be wired on a lab bench before it's mounted to the NI ELVIS base unit.

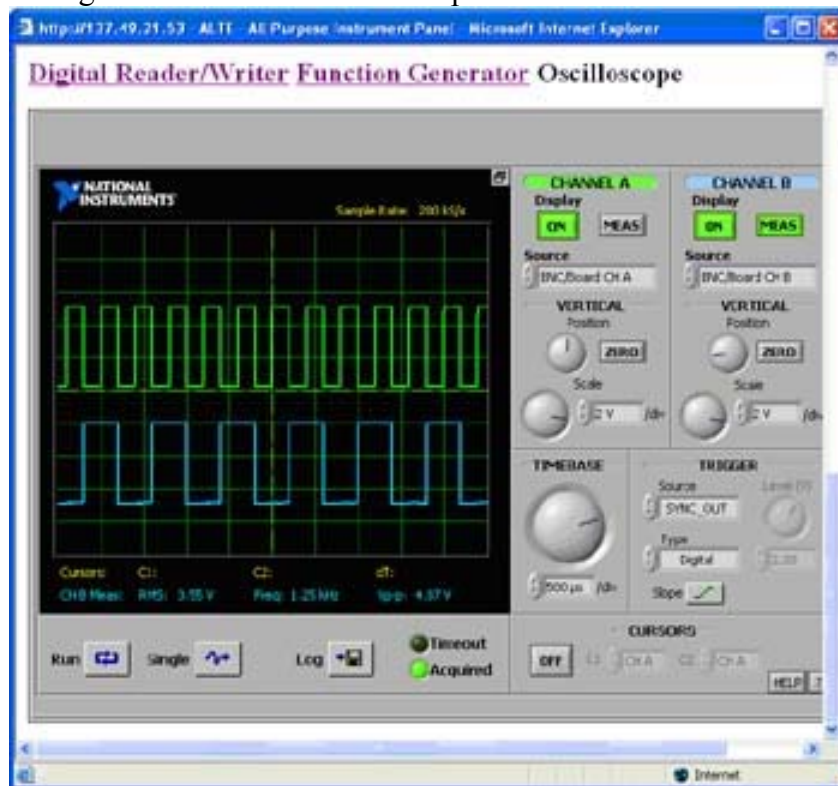
Lastly, the NI ELVIS virtual instruments needed to perform the lab must be incorporated into a web page to be served by LabVIEW. Figure 2 is a picture of the complete NI ELVIS unit with one of the pilot test experiments built on the breadboard.

Figure 2. NI ELVIS Unit



NI ELVIS units are supplied with virtual instrument panels (VIPs) that are accessed by LabVIEW. Each NI ELVIS instrument has a specific VIP associated with it. To reduce the number of open browsers, we integrated all of the instruments for each lab onto one browser window. A simple navigation menu using bookmarks was inserted so students could easily switch from one instrument to another. Figure 3 shows a screen shot of the oscilloscope VIP.

Figure 3. NI ELVIS Oscilloscope Virtual Instrument Panel



During the pilot test, both NI ELVIS lab stations were located in a network closet as shown in Figure 4. Each NI ELVIS lab station was connected to a dedicated PC running LabVIEW 7.1 that served web pages containing the embedded instrument panels. After the ALTE management server verified that a student had a specific distance lab reserved, their browser was re-directed to the appropriate lab station.

Figure 4. Photograph of NI ELVIS2 Lab Station



ALTE Pilot Test

For the pilot test, we chose two fundamentals electronic courses and conducted two experiments in each course in a distance format. The combined enrollment of both courses was 31 students. The first course was AC Circuit Analysis, a second year 4 credit course taken by students in four programs: Electronic Engineering Technology (EET), Computer Engineering Technology (CET), Audio Engineering Technology (AuET) and Music Production Technology (MPT). The second course was Electronic Fundamentals, a second year 4 credit course taken by students in the Mechanical Engineering Technology (MET) program. During the pilot test, each course had dedicated access to one of the two NI ELVIS lab stations.

Figure 5 shows the four experiments that were part of the pilot test. In each course, the first distance experiment was set up on an NI ELVIS unit and made available for 10 days. Afterwards, the second experiment was set up and made available for another 10 days. The distance labs were run in weeks 12-14 of the 15 week semester. Since ALTE had two production lab stations, both courses were able to offer their distance labs simultaneously.

Figure 5. Courses and Distance Labs in the Pilot Test

Course Name	Programs Represented	Enrollment	Online Lab Name
AC Electrical Fundamentals	EET, CET, MPT, AuET	25	Series RL Circuits
			Parallel RL Circuits
Electrical & Electronic Fundamentals	MET	6	Basic Digital Gates & Combinational Logic
			J/K Flip Flop Circuits

Prior to conducting an experiment, a student was required to reserve time on ALTE. They were limited to a maximum of 2 hours per lab session, but could reserve additional time at the conclusion of each session. Since each distance lab was online for 10 days, a total of 240 one hour timeslots were available which equated to 15 hours/student for the first course and 40 hours/student for the second course.

In both courses students were required to submit written lab reports for both onsite and distance labs. The sections of each lab report were the same: Objective, Procedure, Results and Conclusions. The lab reports were graded by the same instructor using the same criteria.

At the end of the course, students who performed at least one distance lab were surveyed and asked questions about their experience. The purpose of the survey was twofold. First, we wanted to uncover any technical issues either with the ALTE system, LabVIEW or the NI ELVIS VIPs. Second, we wanted to learn how students viewed the relative value of distance and onsite labs.

Pilot Test Results

Of the 31 enrolled students, 22 performed one or more of the distance labs for a total of 33 distance labs. The average connection time varied from a low of 1.7 hours to 5.2 hours. Both groups of students took less time on the second lab as students became more familiar with ALTE and the VIP interfaces. The number of students who performed the second distance lab was significantly less than the first lab. Since their lowest lab score was dropped for the purpose of computing their lab grade, many chose not to perform the last lab if it wouldn't have improved their overall lab grade.

Figure 6. Online Lab Usage Statistics

Experiment	No. of Students	Labs Performed	Connection Time (Hours/Lab)
Series RL Circuits	16	16	5.2
Parallel RL Circuits	16	7	2.9
Basic Digital Gates & Combinational Logic	6	6	2.5
J/K Flip Flop Circuits	6	4	1.7
Total	22	33	3.8

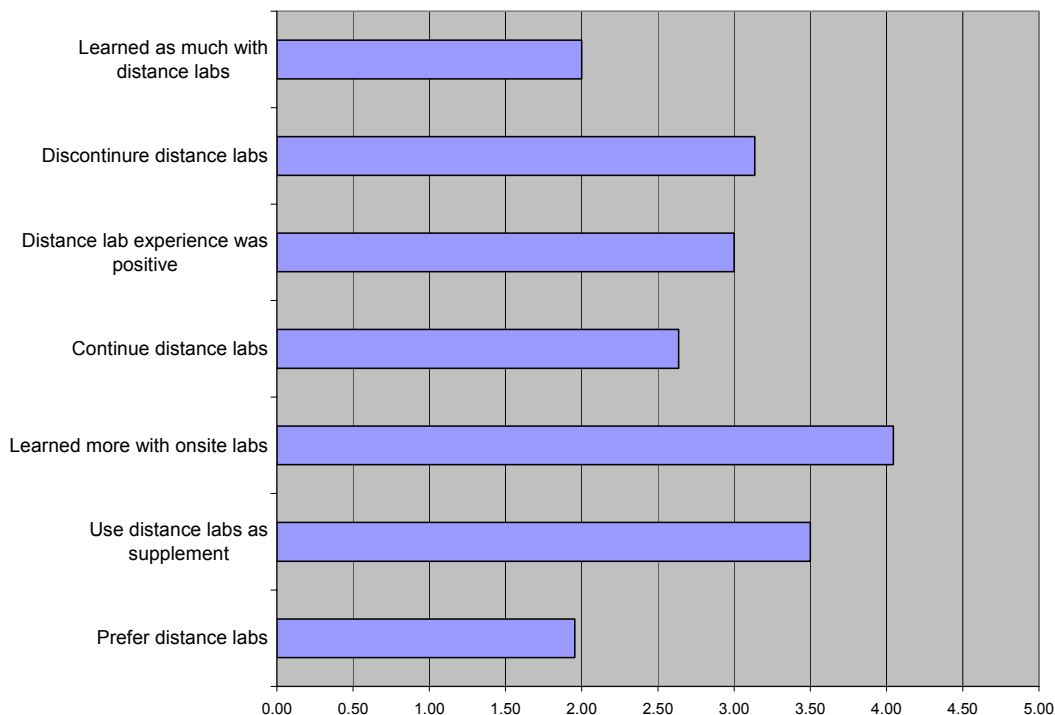
The lab reports were graded by the same instructors, and the same criteria was applied to both onsite and distance labs. Figure 7 shows the lab report averages, and there was no significant difference.

Figure 7. Lab Report Grades

Statistic	Average
Average Lab Report Grade (Distance)	91
Average Lab Report Grade (Onsite)	88

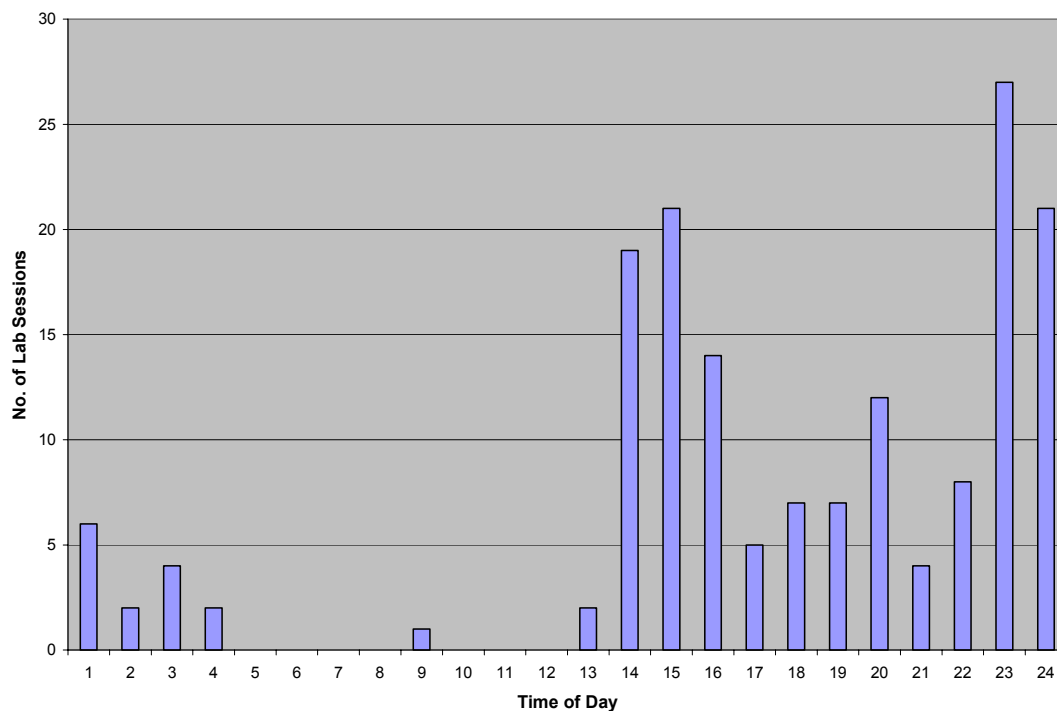
Students that performed one or more of the distance labs completed a questionnaire and were asked to rate seven statements on a five step scale: strongly agree (5), agree (4), neutral (3), disagree (2) and strongly disagree(1). The results are shown in Figure 8. Students expressed a strong preference for onsite labs which wasn't surprising, but most felt the distance lab experience was positive. There was a split between those that saw value in distance labs as supplemental to onsite labs and others who thought distance labs should be discontinued.

Figure 8. Student Questionnaire Results



Another interesting statistic was the time of day when students performed the distance labs. Figure 9 shows a bi-modal distribution with one cluster of students from 1pm to 5pm and another from 8pm-12pm. Very few students performed distance labs between 5am and 1pm. This was valuable information in ALTE capacity planning.

Figure 9. Usage by Time of Day



Conclusions

The ALTE platform worked extremely well in delivering the distance labs. The two most common problems reported by students were remembering to turn off their desktop firewall and pop-up blockers (especially with MS Windows XP). Either prevented the virtual instrument objects from being viewed. Improvements in the Help/FAQ areas will be made to assist students in resolving these kinds of issues. Only two students complained about having to make a reservation in order to run a distance lab. Several students suggested embedding a circuit diagram on the virtual instrument panel itself to make it easier to “see” what was being measured.

Students successfully ran all of the distance labs, and the overall time spent in experience-based learning was equal or higher than with onsite labs. However, given a head-to-head choice, students expressed a strong preference for onsite labs. Most view the lab experience as best done in person with an instructor and other students present. However, they rate their distance experience as positive, and see it as a good way to supplement their onsite laboratory work.

From the connection time data, students spent a lot of time getting used to the remote control panels in the first experiment. The connection came down significantly for the second lab. We concluded that it would be better to include a least four distance experiments in a course so the student’s investment to download/install the LabVIEW runtime engine and master the control interface could be better leveraged.

A follow-on pilot test is scheduled for the spring 2005 semester, and again, two courses will be chosen. However, four distance labs will be performed in each course to double the student’s

exposure to distance labs. The results of both pilot tests will be used to improve the ALTE delivery system, lab procedures and distance experiments themselves.

Based on the results of the pilot test, we see a variety of ways to integrate distance labs into our future curriculum. For fulltime, on-campus students, distance labs could be used as make-up, extra credit or supplemental work. They are especially useful for “predict and measure” experiments that focus on analytical learning. Onsite labs could then focus more on design and troubleshooting. Lastly, distance labs could be used to increase access to one-of-a-kind equipment that now must be shared in large groups. This is especially true in upper term courses where advanced test equipment is most used.

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