Remote Labs Environments (RLE): A Constructivist Online Experimentation in Science, Engineering, and Information Technology

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Abstract – ***Since the invention of the Internet, many academicians, educators, and researches have been searching for effectual virtual lab experiments; however, the very nature of real experimentation was not possible or missing. Yet, in the past few years, many scholarly articles and published research reports claimed the availability of virtual laboratories that mimics real laboratory experimentations. Nonetheless, within these self-claimed virtual experiments' infrastructures, the elements of real experimentation- in comparison to conventional laboratories were far distant from constructing real experimentations online. Such a lack of real experimentation, over the internet, gave birth to an authentic leap beyond the limitations of antiquated virtual laboratories. The recent birth of Remote Labs Environment (RLE) at the Centre of Advanced Distance Education Technologies (CADET) brings with it a world of possibilities and innovative computing technologies. For this reason, this paper was written to inform and to set forth a discussion of RLE experiments. RLE brings into play a diverse state-of-the-art technologies including but not limited to: single-chip web server/controller hardware technologies, Component Object Model (COM) software technologies, Instructional Design models and an embedded instructional cognitive subsystem (ICD), and in- house middleware applications. RLE's technology is systematically integrated into one unified computing system to help institute real experimentation environment [5] online. All experiments presented in this paper were actually designed and implemented in CDA6316 grad course (Embedded Systems, taught by one of the authors of this paper). These experiments will be used in undergraduate engineering courses, where students get to manipulate experiments online and from different remote locations.***

I. INTRODUCTION

RLE is encompasses different state of the art technologies (e.g. software, hardware, middleware which serves as a cognitive instructional systems, and other peripheral computing technologies). RLE allows students and teachers to perform experiments at a distance where flexibility, comfort, and ease of experiment manipulations are positive advantages [13]. As the world changes at an accelerating rate, more people are seeking flexibility of scheduling, the possibility of proceeding at one's own pace and the opportunity to learn without having to travel, indeed without leaving home [21]. Such a need gave an explosive market boom to numerous online education where some deliver quality education, but others do not! Simply said, some online institutions of higher education became diploma mills. According to the Princeton Review (2004) quoting the National Center for Education Statistics (NCES), the number of educational institutions offering distance education has seen explosive growth in recent years. In addition, a continuous growing number of colleges and universities promote new ways of pursuing degrees and taking college courses, people seeking quality education at a distance are now challenged by the broad range of choices available—some are good and some are bad. For example, NCES reported that in 1999-2000, among all students who participated in distance learning, 60 percent did so through the Internet, 39 percent through pre-recorded audio or video and 37 percent through live television or audio. Among undergraduates, females were more likely than males to participate in distance learning, as were students over the age of 24 than younger students [22].

Such a demand for quality distance education, cultivated the need for RLE that caters its services to real experimentation and quality education online. By using up to date micro-controller technologies, the design and implementation of RLE described in this paper, have become extraordinarily more compact and inexpensive [5]. On the other hand, by systematically design instructions, quality was monitored and enhanced each step of the design process. RLEs do not impound user's environmental or personal limitations (e.g., physical, personal, or contextual resources, technologies' limitations, and the like) because it bridges the currently existing crack between software simulation (SS) and traditional lab experimentations [2-6]. Moreover, some additional advantages of remote labs are the following: cost-benefit utilization and optimization, optimum maintenance consistency, student-experiment safety, parameters controlled flexibility, digital archiving, experiment videotaping, video steaming, and playback-repetitions, limited and open file security and sharing, quality design of instructions, systematic implementation and evaluation of contents, and time and source-resource sharing.

Moreover, RLEs' greatest advantage is its ability to offer persons with disabilities the opportunity of attending an engineering or science course and experimenting on-line without having to face the traditional limitations of physical (conventional) laboratories.

Furthermore, Remote Laboratories used in delivering courses online, supplement learners' diverse needs and supplement quality distance learning modalities. RLEs are designed to accommodate the modern needs of distance education for learners who wish to study off campus yet not lose quality instructions and facilitation of quality education [8-11; 17, 18]. By designing the hardware for the experiment in advance, a student at a remote site (e.g. Dubai or London) can access the experiment's home page, regulate experiment's parameters run a test, save it, and play it back as needed or re-manipulate it as needed. The results are then returned to the user's web browser for analysis [5-7].

II. SYSTEM DESIGN

Since its quite simple beginning in the summer of 1999 at CADET, it has stretched to embrace a mix of information technologies- some are standard technologies and others are created in-house. As mentioned earlier, RLE technologies were created with the user's instructional needs and learning affordances and limitations in mind [17-19]. Cognitive Instructional System (CIS) as a RLE sub component; for instance, was developed based on modern design of instructions, learning psychology, and user's learning behaviours in mind [18,20]. As the impact of psychology on human learning progresses, CIS was created with goal of producing optimal learning at a distance.

RLE was explicitly intended to improve students' learning and cognitive skills by using RLE as computing-cognitive tools (not only as computing tools: e.g. hardware/software for I/O processes) remotely and beyond the employment of mere software simulation modality- which limits students' creativity and sense of reality. During the systematic design of instructions, for example, RLE developers focused on the improvement of users' metacognitive strategies and other learning skills to augment students' skilled decision-making processes- especially in novel and complex problem solving conditions [6-12; 17, 18]. A typical RLE model is illustrated in Figure 1.

III. ACTIVE ELEMENT EXPERIMENT SETUP

In this section we discuss the design of an on-line Electrical Engineering experiment that explores the measurement of a BJT transistor gain factor. This was one of the 4 main experiments build in the grad course CDA6316 in the Spring of 2005. The other three are Passive Element (resistor) IV Characteristics, Motion and Friction on a Reclined Surface, and Web-based Home Automation System. All these experiments will be used for undergraduate engineering courses where students are able to manipulate real experiments online via the use of RLE (currently located at FAU in the CADET). For instance, the measurement of the BJT gain itself is a part of the lab curriculum for the undergraduate electronics engineering laboratory. By using our RL environment, electronics engineering students are capable of doing this experiment remotely without the need to attend on campus laboratory.

The RL system for the BJT transistor experiment is mainly comprised of 4 critical blocks as shown in figure 2: the network enabled micro-controller, a Digital to Analog Converter (DAC), a sweep voltage power supply, and the transistor being tested for its IV characterization. Once configured, the RL system is connected to the Internet and becomes ready for remote end users. The system does not require any special hardware or software requirement at the user's end, besides the Internet browser.

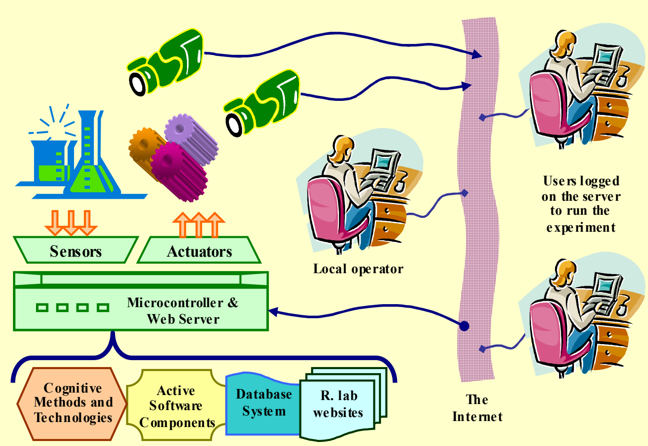

Figure 1.
Remote Lab Environment (RLE) Components

A. Hardware issues

The microcontroller block of the experiment is based on the Freescale Semiconductor MC9S12NE64 micro-controller / DEMO9S12NE64 evaluation board [16]. This evaluation board was selected for its integrated on die Ethernet controller, fast processing speed and externally available IO pins. However, it contains only 64KB of Flash and 8KB of RAM which must be shared between application and constant web page data. This severely limits the amount of functionality that a given experiment can contain. Future versions of the Active Element experiment will utilize some of the expanded IO capabilities of the chip for the addition of external memory where constant web page data may be stored. This would increase the space for application code dramatically. An eight bit IO port is used to adjust the output of the external DAC which in turn adjusts the base current, Ib, of the transistor under test (Figure 1). Two internal analog to digital converts measure the sweep voltage, Vsweep, and the transistor's collector voltage, Vc. The collector current, Ic, is calculated by dividing the differential voltage drop on the collector resistor, Rc, by the value of Rc.

$$I_C = \frac{V_{Sweep} - V_C}{R_C}, \qquad (1)$$

Were Vsweep is a constant sinusoidal input with an adjustable peak voltage of 3.3v and minimum voltage of ~0.0v.

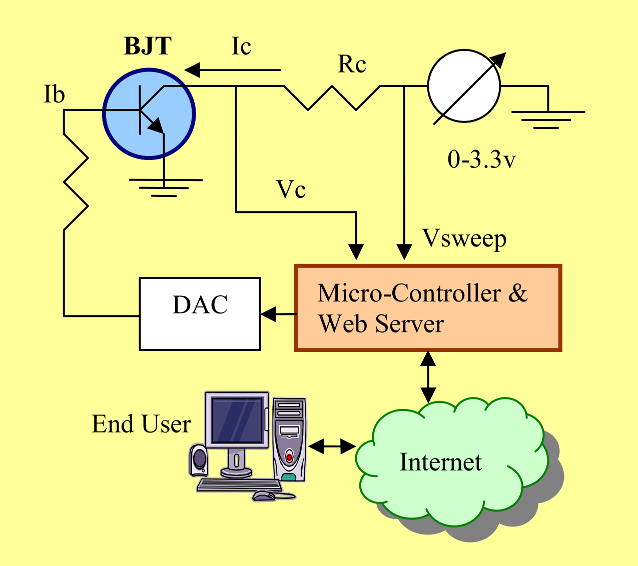

Figure 2.
The Overall BJT Experiment Building Blocks

B. Software Design

An evaluation board from Freescale is relatively inexpensive and is offered with a demonstration of OpenTCP, a free TCP/IP stack. A simplified flow chart depicting overall software operation is shown in Figures 3.a and 3.b. With the exception of the Ethernet data arrival, and real time interrupt, all software functions are polled from within the main loop.

The Active Element (AE) experiment's embedded C code was compiled using the Metrowerks Codewarrior IDE for HC12 embedded micro-controller devices.

The ActiveX control that resides on the embedded web page was designed using Microsoft Visual Studio 6.0. All web page files including the ActiveX control were crunched into C arrays using a freeware tool called CEncoder.exe and their file names where hashed using HashCalc.exe. Both CEncoder and HashCalc are provided as part of the OpenTCP project. A P&

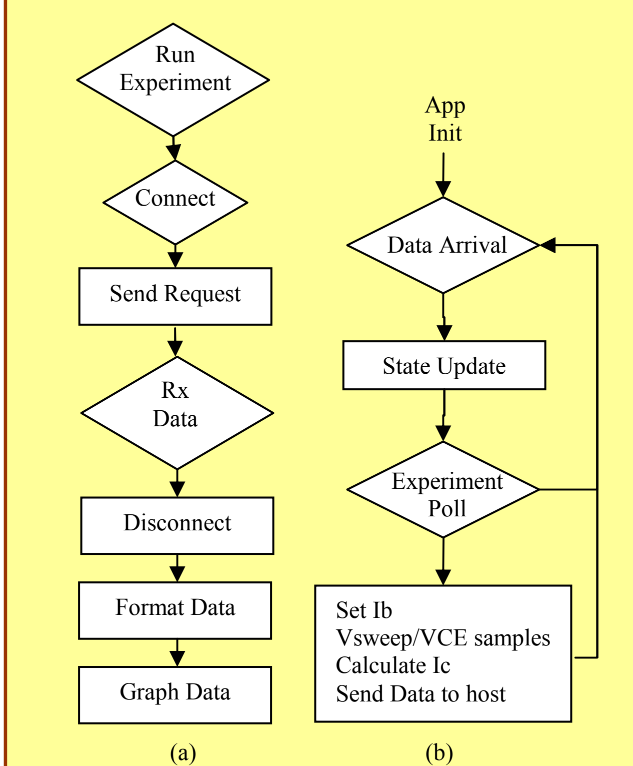

Figure 3.
(a) Overall Software Operations, ActiveX Control
(b) Overall Software Operations, Embedded Software

C. The Cognitive Instructional System Component (CIS)

As mentioned earlier, the cognitive instructional system component of the actual RLE infrastructure is an embedded design (middleware) that comprises of a comprehensive implanted element of all working devices, software, hardware, and firmware [1-4;17,18,19]. It is simply an in-house middleware that was developed to serve a diverse body of learning needs for the non-traditional and traditional user. Students' instructional needs (software documentation, instructional clarity, assessments, technical manuals and ease of online experiment navigation) were all considered in creating this unique component. Thus, from an educational point of view, it is this component of the RLE that helped add a pedagogical sense to the over all design to better construct an effective human-computer-interaction (HCI), and to offer students an extensive flexibility of modalities and choices. Thereby, providing the optimal combinations of interaction and media, [22-25].

D. Running the Experiment

When an End User connects to the embedded web server, a web page with an embedded ActiveX control is returned. When the ActiveX control loads, the user has the option to adjust the base current (Ib) to 2, 5, 10, 15, or 20 micro amps through a drop menu. When the Run Experiment button is selected, periodic samples of the collector current (Ic) and the collector voltage (Vc) are returned to the ActiveX control where an Ic vs. Vce graph is created for evaluation.

Using a custom Visual Basic configuration utility, the Remote Lab Administrator can make configuration changes to any of the running experiments without recompiling any of the experiments underlying source code. This makes formal changes to the network infrastructure much easier and also allows for modification of the experiments operating parameters. In the case of Active Element, if the Lab Administrator wished to modify Rc, he could physically change the resistor and update the software algorithms accordingly as shown in Figure 4.

E. Analysis

As a result of varying Ib, values for Ic and Vc change. The table below shows the average of these variations after several runs of the experiment.

TABLE I . Results of varying Ib, values for Ic and Vce

Ib (uA)	Ic min (uA)	Ic Max (uA)	Vce min (mv)	Vce Max (mv)
2	0	299	0	3016
5	0	793	0	2548
10	0	1534	0	1729
15	0	2340	0	962
20	0	2990	0	273

The result of the experiment is consistent with the traditional circuit analysis and confirms that a dependency between Ic and Ib exists as shown in Figure 5, and as the amount of current drawn through the transistor from collector to emitter increases, the voltage at the collector decreases.

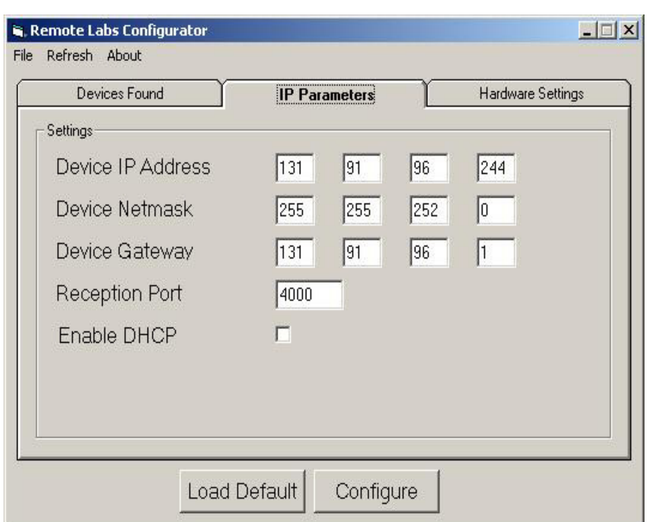

Figure 4. IP and General Administrative Utility Menus

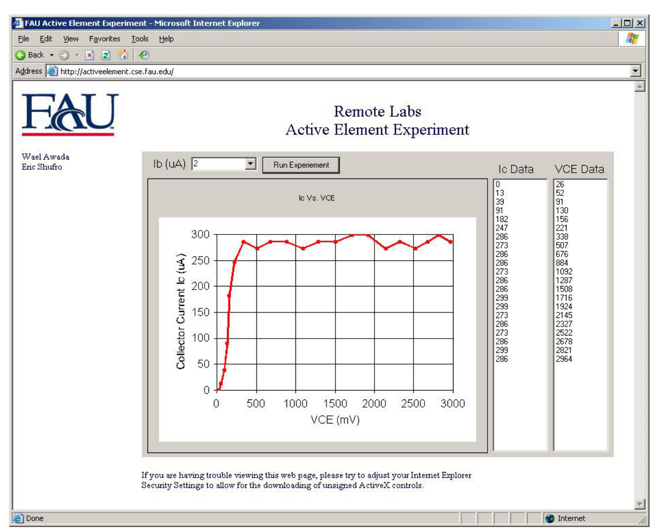

Figure 5. Snap shot of the resulting waveform, IV

IV. DESIGN ISSUES

The OpenTCP web server implementation does not return HTTP headers thus causing problems with some web browsers loading the page. Moreover, there is a total of 64 KB of on die flash memory divided into 4 pages and none of the pages are contiguous in the memory map. This implies that no single source file can be larger than 16KB. Also, due to the simplicity of the OpenTCP web server, all active content must be in the form of a Java applet or an ActiveX control. This automatically means larger source files which is problematic. If the web server were slightly more complex, then html based forms could be used to post data to the web server which in turn could generate dynamic web page content to be sent back to the end user. An example of this might be the ability to view the system uptime through a web page as opposed to an ActiveX control. Finally, if external storage were attached to the MC9S12NE64, and a file system driver were added, the project would still be crippled by the small amount of RAM available. Unfortunately, the DEMO9S12NE64 evaluation board does not provide enough external IO to memory map external RAM modules. Therefore, a future version of the experiment would likely be built around a less expensive and more powerful processor and evaluation board such as the Sharp LH79524 ARM7TDMI with integrated Ethernet.

The ActiveX control was initially 19KB before optimization. Lastly, Microsoft's security settings for Internet Explorer imposed restrictions on the loading of ActiveX controls by default. In order to get the control to load, users need to adjust the 'download unsigned ActiveX controls' option to 'prompt or enable'.

V. CONCLUSION AND FUTURE WORK

RLE is not to be misunderstood as a replacement for conventional labs or simulation software applications; however, RLE is an augmentation tool and supplemental modality to help enhance the learning experience, at a distance. RLEs have great potentials for expanding distance learning for traditional and non-traditional students, learners, employees, and professionals-- beyond confined classroom and laboratory environments. For example, Active Element is one of many of the possible experiments that can be conducted using this innovative technology. RLE's future development will continue to add innovative functionality with greater precision and higher quality of instruction. The experiments described in this paper illustrate to its readers a new technology that is whole and purposeful (e.g. embedded web servers, hardware technology, Component Object Model, and Cognitive Instructional System). All of these information technologies are integrated, shared, and embedded within one complete system to build on-line experiments [5] when needed and as needed. The authors' work is still in progress and aims to serve learners who might come from all walks of life. A target population that is diverse in nature and in need for quality education at a distance.

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