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Developing a Remote Laboratory at TAMUQ Based on a Novel Unified Framework

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ABSTRACT

In order to benefit teaching engineering courses while sharing resources with other universities and colleges, a remote laboratory has been successfully developed based on a novel unified framework. The laboratory is established through a collaborative effort between three universities which are Texas A&M University Qatar (TAMUQ), University of Houston (UH) and Texas Southern University (TSU). Two remote engineering experiments are designed and implemented in the off-site laboratory for teaching purposes, and a generic scheduler is developed for managing the distance operations. End-users can remotely operate or view real-time procedures through most current web browsers on any PC or portable device without firewall issues and the need for a third party plug-in. Student survey data are collected from a mechanical engineering course teaching by using the off-site laboratory at TAMUQ. The survey data are also presented and analyzed in the paper.

INTRODUCTION

The concept of a remote laboratory implies the use of Internet and system control technologies to conduct real-time experiments from alternate sites. Because of the effectiveness, flexibility and cost-savings of a remote laboratory, many applications are being recognized in science, technology, engineering and math (STEM) education. These laboratories can be highly effective tools for helping a wider range of students, regardless of geographic constraints, to obtain practical experience needed for competency in science and engineering. This location-independent access is especially useful in scenarios where space is limited, or for distance education [1]. The concept of a remote laboratory was discussed in parallel with the introduction of the Internet in the 1970s and has evolved from the union of online-learning programs, such as MIT OpenCourseWare, PROLEARN, and other distance laboratory efforts around the world [2,3]. More than 100 remote laboratories for different types of applications can be found around the world resulting from both individual efforts as well as large scale, multi-national, multi-institutional efforts [3]. Newer modalities of remote laboratories are now beginning to appear, including a LabVIEW-based triple access mode (hands-on, virtual, remote virtual, and remote) laboratory [4], and even multi-user remote laboratory systems [5]. Some of the most prominent examples of remote laboratories are briefly described below, with emphasis on their purpose, architecture and platform.

- **iCampus iLabs:** The iLab at Massachusetts Institute of Technology (MIT) has developed a "distributed software toolkit and middleware service infrastructure to support Internet accessible laboratories and promote their sharing among schools and universities on a worldwide scale." [6].The iLab is based on Client-Server Architecture.
- **WebLab-Deusto:** WebLab-Deusto is an "open-source distributed remote laboratory used with students at the University of Deusto since February 2005 and is an essential tool for practice in different engineering-related subjects. It makes possible the offering of real

experiments (e.g., FPGA, CPLD, PIC microcontrollers) to a particular group of users through any computer network." [7]. This remote laboratory uses Browser-Server architecture software.

- **UTS Remote Labs:** UTS Remote Labs is "part of Lab share, an Australian Government funded project that aims to create a national network of shared, remotely accessible laboratories." [8]. This lab also uses Client-Server architecture software.
- **LiLa (Library of Labs):** LiLa was created from the alliance of the eight European universities and three enterprises. The goal of LiLa is "the composition and dissemination of a European infrastructure for the mutual exchange of experimental setups and simulations, expressly targeted toward undergraduate studies in engineering and science." [9] In LiLa, there are virtual laboratories (simulation environments) and remote laboratories (remotely controlled, real laboratories via the Internet). For the implementation of remote laboratories, a browser plug-in can be used to gain control over all devices. LiLa uses a Browser-Server architecture remote laboratory system with plug-in capability.
- **Smart Material Remote Labs:** The goal of the remote laboratories at University of Houston (UH) is to provide users with an interface that will work in most Internet-enabled web browsers without the need to install a software plug-in [10].
- **Virtual and Remote Laboratory (VR-Lab):** Collaboration with UH, Texas Southern University (TSU) is carried out to develop a plug-in free remote experiment platform. Data Communication virtual and remote experiments and the remote Digital Signal Processing (DSP) experiments were designed. Their remote laboratory is also the Browser-Server architecture software system. [11].

As shown above, off-site, distance-accessed laboratories are a vibrant area of research, and there is continuous development leading to innovative methods of delivering laboratory experiences independent of physical location. Research indicates most of these laboratories above are based on two software architecture paradigms: Client-Server architecture and Browser-Server architecture. Most of recently developed remote laboratories are based on Browser-Server architecture. Usaually, the remote laboratory includes: a server to host remote experiments, the experiment device itself, a local computer workstation which is used to control the experiment device and plays a role as gateway between server and experiment device, remote access devices (PCs or mobile devices), and users. Most of the devices must be locally handled by a workstation in order to be controlled over the Internet.

Some challenges remain and are as of yet are unresolved which are as follows: *1.) How to improve the lack of reusability issues in system deployment 2.) How to improve cross-platform performance and resolve the client-side software without plug-in issues 3.) How to resolve the real-time experimental data and experimental video traversing network firewall transmission issues 4.) How to improve the experimental device compatibility issues and 5.) How to improve system security issues.*[12,13]

To address some of the essential challenges such as cross platform access and third party plug-in free etc. which are listed above, a novel easy-to-use unified framework has been designed and implemented through the collaborative effort of Texas A&M University Qatar (TAMUQ), University of Houston and Texas Southern University.

METHODOLOGY

To implement a remote laboratory, there are two tasks needed to be accomplished: software platform development, and the experimental hardware platform set up. This software platform is based on the novel unified framework we proposed and developed.

The Novel Unified Framework for Remote Laboratory Development

The novel unified framework is based on the Web 2.0 technology and includes three parts: the client web application, the server application, and an experiment control application. The client web application runs on most popular browsers and is based on HyperText Markup Language (HTML), Cascading Style Sheets (CSS), and JQuery/JQuery-Mobile JavaScript libraries; further, it uses Mashup technology for user interface implementation. The server application is based on Web Service technology and is directly built on top of a MySQL database an Apache web server engine, and Node.js web server engine [14,15]. The server application also uses JSON and Socket.io [16] which was developed based on web socket protocol to implement the real-time communication between the server application and client web application. The server application runs on a Linux server. The experiment control application is developed with the LabVIEW, and also uses Socket.IO to real-time communicate with the server application. The experimental application runs on a Windows workstation. For the entire novel unified remote laboratory framework, three vital technologies are primarily used in the implementation, These technologies are Socket.io and Node-HTTP-Proxy used for experiment data and control commands transmission and traversing firewall, a novel video transmission approach is based on HLS protocol for real-time system monitoring, and Mashup technology is used for user interface implementation. The new framework also makes two crucial improvements: real-time experiment live streaming video across firewall transmissions [17], and real-time control command and experimental data transmission across a firewall [18]. The Table 1 depicts the technical characteristics of the improved unified remote laboratory framework in detail.

Table 1. Technology/protocol/software list for the new solution.

	Name	Technology/Protocol/Software	Remark
1	HTTP Proxy	Node-HTTP-Proxy	Part of Node.js
2	Data Protocol	Socket.IO	Part of Node.js
3	Real-time experiment video transmission	HTTP Live Streaming Protocol /FFMPEG /Segmenter software package	
4	Database	MySQL	
5	Client – User Interface	Mashup technology, JavaScript	
6	Server - Web Service	Apache, Node.js, JSON	LtoN (LabVIEW to Node.js)
7	Equipment Control	LabView	

To address the network security concern, an isolated experimental network for the remote laboratory is established. In this private network, all experimental equipment is connected to the central server through network switch. The experiment control workstation cannot access Internet even it has network connection with server. This central server controls all the communications between the user and network enabled devices. The user cannot directly access any networked devices such as experiment camera and workstation. Figure 1 depicts the new isolated experimental network architecture.

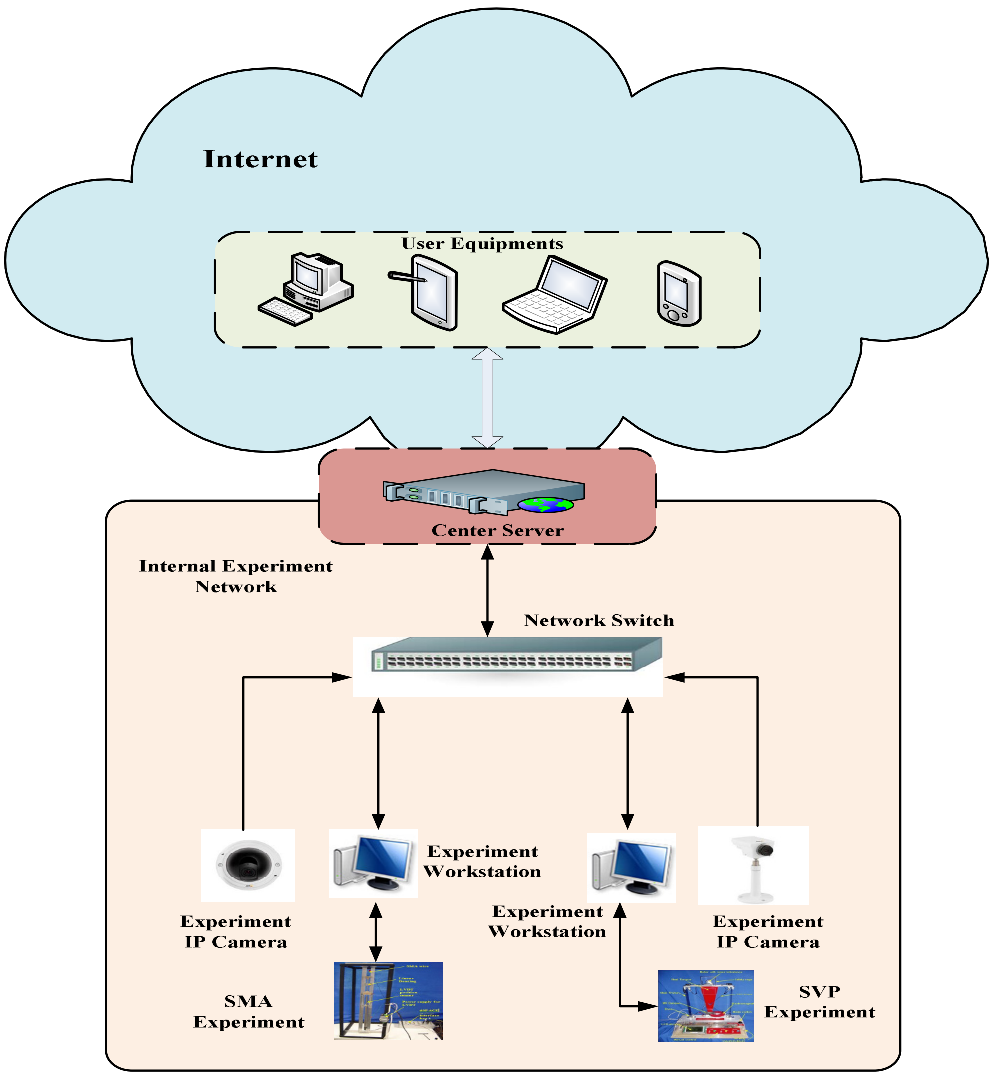

Figure 1. The new isolated experiment network architecture

Two Remote Experiments in Laboratory

Initially, two Mechanical Engineering (ME) experiments, SVP (Smart Vibration Platform) and SMA (Shape Memory Alloy), were incorporated as part of the remote laboratory series used in the Intelligent Structural Systems (ISS) course. This course, which included both senior undergraduates and graduate students, introduced students to the applications of smart materials in structural applications with a strong emphasis on vibration control. In the ISS course, students were expected to learn about the application of intelligent materials, as well as the mechanical principles governing the control of such materials. After completion of these experiments, the students needed to submit a report which included analysis of the experimental data and experimental data.

Hardware Platform Setup of Remote SVP and SMA Experiments

Two remote experiments are developed in the remote laboratory. As shown in Figure 2, SVP experiment, and Figure 3, SMA experiment, are ready for use via the Internet.

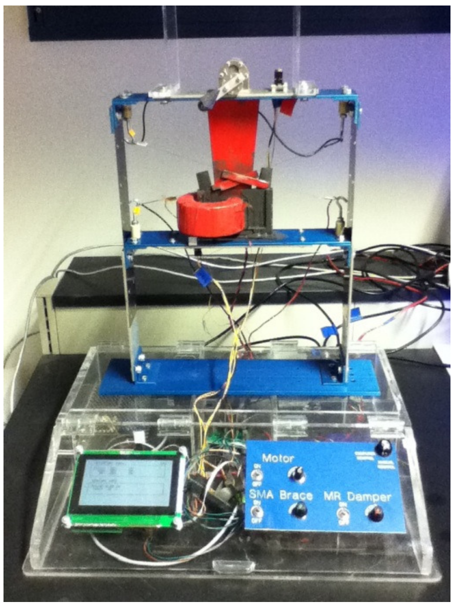

Figure 2. SVP experiment

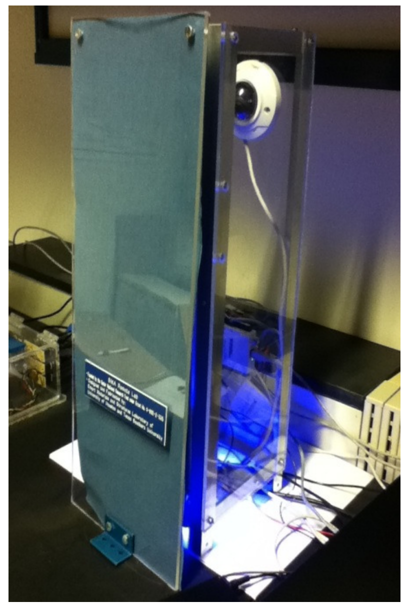

Figure 3. SMA experiment

Remote SVP Experiment: The SVP device, as shown in Figure 2, is assembled by using fabricated and purchased components. The SVP has a two-story flexible steel frame fixed on top of a plexi-glass box. In the plexi-glass box, there are electric circuit boards made to control the experiment. It is designed and built by students in the Smart Materials and Structures Laboratory at the University of Houston. Other than the flexible steel frame, the SVP has a motor, SMA wires and a purchased magnetic iron clamped on a container of Magneto-Rheological (MR) fluid. The motor with a weight is mounted on the top of the frame and connected to the driver from the box on the bottom. When the user controls the current going through the electrical circuit, the speed of the motor can be adjusted. The rotation of the motor leads the flexible frame to vibrate. Two SMA wires are hung across the frame. When the current goes through the wires, the temperature will increase. At a certain point of rising temperature, the SMA wires will shrink in length to reduce the vibration of the frame; this is called a SMA brace. A red steel tongue is placed downwards into the container of MR fluid. The magnetic iron clamped on the container can generate magnetic field when it is turned on. That increases the viscosity of MR fluid because MR fluid changes from fluid state to semi-fluid state under the magnetic field; this is called MR damper.

Remote SMA Experiment: The SMA device, as shown in Figure 4, is assembled by using fabricated and purchased components also. The mainframe uses L shape aluminum bar fixed by screws. There are plexiglass sheets fixed on several sides of the SMA to protect and decorate the experiment. On the bottom, blue LED lights are used to illuminate the experiment. In the middle of SMA device, a red block is lifted by SMA wire and pulled down by two springs. A power supply, as shown in Figure 5, is connected to a SSR (Solid State Relay) and the SMA wire. The voltage is always set around 16.7 V. The control of the SSR is determined by computer intelligence algorithm. A NI (National Instruments) DAQ 6008 USB based real-time system is used for control and data acquisition. A voltage output from the DAQ 6008 is connected to the SSR. When the voltage output is on, the SSR is on and the 16.7 voltage goes through to SMA, vice versa. The displacement of the block is measured by a linear sensor at the front bottom. The sensor is connected to the voltage output and voltage input of the DAQ 6008. The voltage output from the DAQ 6008 to the sensor is always 4.5 V. When the sensor detects a displacement, it gives a voltage that can be recorded by the DAQ 6008. Three ceramic pulleys are used to perform this movement of the block and the SMA wire. The SMA wire is tied one head to block and the other head to one of the bottom frames.

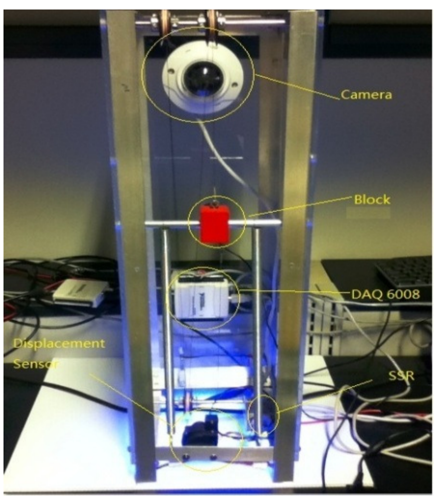

Figure 4. SMA experiment - front view

Figure 5. Power supply

Remote Experiment Camera: Because this is a remote lab, users are permitted to control the experiment remotely, and are allowed to view the real-time response of experiment. So far, two web cameras are connected in the lab. The camera for SVP is placed on a camera tripod in front of the experiment and the other camera for the SMA experiment is fixed on the back side of the SMA. The models of the two cameras are an Axis M1114 for SVP, as shown in Figure 6, and an Axis M3005V for SMA, as shown in Figure 4.

Figure 6. Camera for SVP experiment

Experimental Control Workstations: There are two workstations, as shown in Figure 7, and each workstation controls one experiment device. LabVIEW 2012 (32-bit) is installed on both workstations. Three DAQ 6008 USBs are connected to the workstations, and their voltage outputs and voltage inputs are controlled and sensed by programed code in LabVIEW running on both workstations. These workstations are also connected to our web server via a network. All data generated by LabVIEW is sent to the server. Control commands for the experiment from the Internet are also sent from the server to the workstations.

Figure 7. Workstations

Figure 8. Central Server

Network setup: The server, as shown in Figure 8, is playing the role of communicating with the Internet. All networked devices in an Intranet are connected to the server. The model of the server we purchased is HP ProLiant DL380e Gen8. The network architecture is shown in Figure 1.

Sample Paradigms of Two Remote Experiments

The remote experimental user interface can be run on most platforms without any additional plug-in or software. Only Java runtime engine is required for Microsoft IE for real-time video stream. To demonstrate the effectiveness of the novel unified framework, a revamped remote SMA and SVP experiment is implemented based on the novel framework. Figure 9 and Figure10 illustrate the screenshots on desktop PC, iPhone, and iPad when the users conducted the remote SMA and SVP experiments.

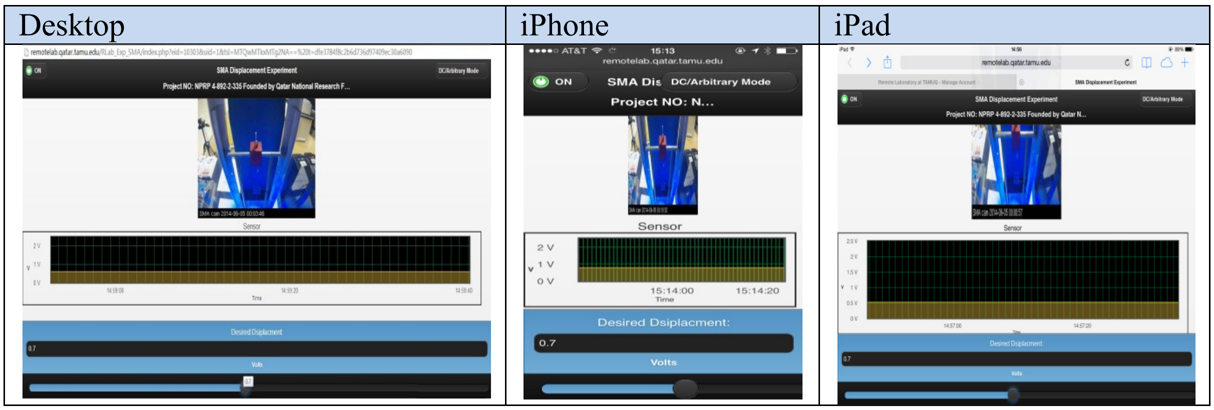

Figure 9. Screenshots of SMA Experiment on PC and portable devices

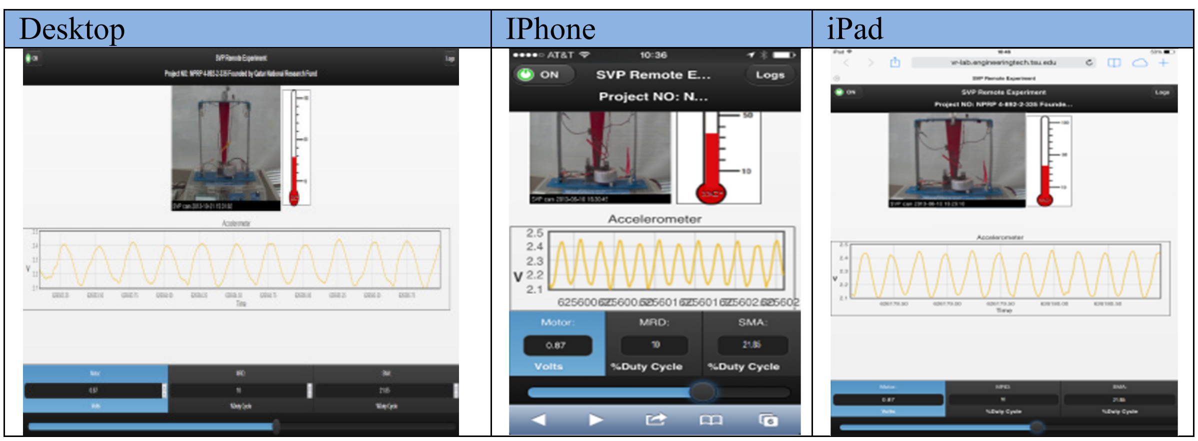

Figure 10. Screenshots of SVP Experiment on PC and portable devices

Here, the remote SMA experiment is used to illustrate the remote experiment operation. When the power indicator on the left corner of the user interface is turned on, the user can move the slide bar by changing the control values of experiments. The sensor output, which indicates the real-time experiments output values, is shown in the middle of the web page. With our novel data and video transmission solution, the real-time experimental video can be transferred to different platforms without a firewall issue. The capability of running remote experiments on portable devices (such as Android phone, iPhone, iPad etc.) will significantly increase the instrument utilization and will let users gain insights by observing and interacting with the real instrument in an efficient way.

SURVEY RESULTS OF USING THE REMOTE LABORATORY

As a pilot example, the remote Smart Vibration Platform experiment was used in selected mechanical engineering courses being taught. A student satisfaction survey was designed for this pilot remote experiment and, in the survey, there were nine statements with four grades of satisfaction levels used to measure the survey statements. The survey metrics are listed as follows:

- 4 - Very Effective/Very Friendly/Strongly Yes
- 3 - Effective/Friendly/Yes
- 2 - Somewhat Effective /Somewhat Friendly/No
- 1 - Not Effective/Not Friendly/Strongly No

Table 2 shows the results of the survey. In the table, all survey statements presented were designed for students who selected the Mechanical Engineering (ME) courses, and the Average Response Score (ARS) is calculated through the feedback of students based on the survey metrics. The Opinions Implication of Average Score (OIAS) gives the detail illustration of the mean about the ARS.

Table 2. Average Response Percentage by students

	Survey Statements	Average Respons e Score	Opinions Implication of Average Score
1	How effective is the remote experiment to help you to learn about shape memory alloy materials	3.5	87.5% say that it's effective to help them to learn about shape memory alloy materials
2	How effective is the remote experiment to demonstrate vibration control using shape memory alloy wire braces	3.7	92.5% believe that the remote experiment is effective to demonstrate vibration control using shape memory alloy wire braces
3	How effective is the remote experiment to help you to learn about Magneto-Rheological Fluid	3.1	77.5% feel that the remote experiment is effective to help them to learn about Magneto-Rheological Fluid
4	How effective is this remote experiment to demonstrate damping adjustment using Magneto-Rheological Fluid material	3.5	87.5% think that this remote experiment is effective to demonstrate damping adjustment using Magneto-Rheological Fluid material
5	How effective is the remote experiment to demonstrate to demonstrate vibration control using Magneto-Rheological Fluid	3.5	87.5% consider that the remote experiment is effective to demonstrate vibration control

			using Magneto-Rheological Fluid
6	How effective is the remote experiment to help you to help you to learn about Smart Materials	3.7	92.5% think that this remote experiment is effective to learn about Smart Materials
7	How friendly is the graphical user interface for the remote experiment	3.5	87.5% say that the graphical user interface for the remote experiment is friendly
8	The overall effectiveness of this remote experiment to assist your learning	3.4	85.0% feel that this remote experiment is effective to assist their learning
9	Are you willing to see more remote experiments to help you learning in your future classes	3.5	87.5% students willing to see more remote experiments to help them learning in future classes

Figure 11and Figure 12 are bar charts that show the survey results vividly, and, for all of the survey statement items, the ARS level is more than 3.4 and the OIAS level is more than 87%. This result means that most of the students selected effective or very effective level. With the overall level of OIAS is more than the average level, it can be concluded that a clear majority of the students in the pilot consider the remote experiments, based on the novel unified framework, effective in helping them gain practical experience and knowledge.

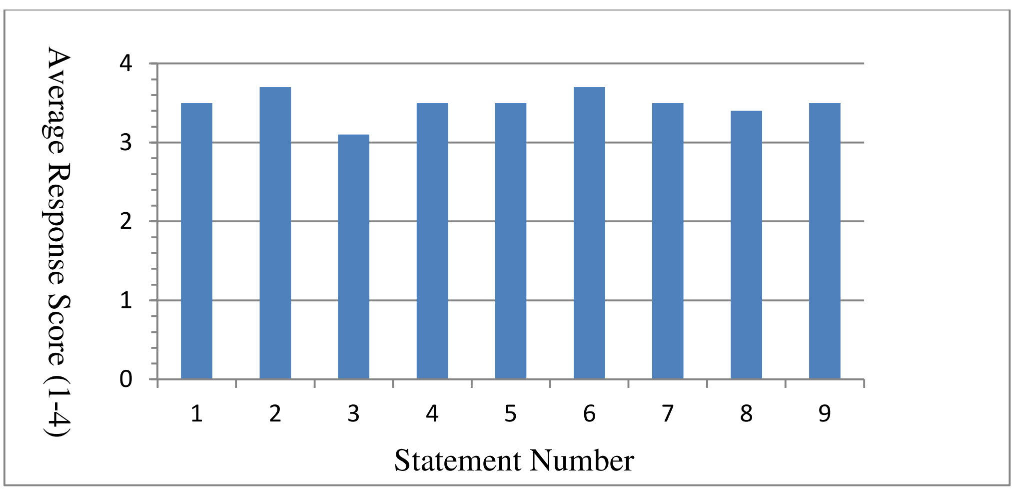

Figure11. Graph of Average Response Score

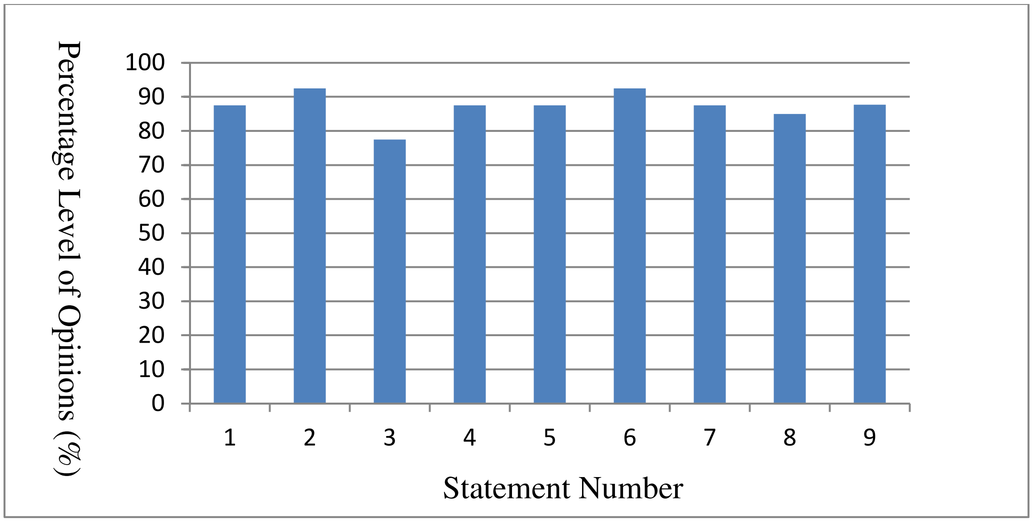

Figure12. Graph of Percentage Level of Opinions

As Table 2 illustrates, if we assume the following percentages matrices to measure the OIAS:

- 80%-90% -Notable effective/Friendly
- 60%-79% -Effective/Friendly
- Below 59% -Weak Effective/Friendly

Then the following survey conclusions can be drawn based on the matrices:

- The remote experiment helped students learn about shape memory alloy materials.
- The vibration control using memory alloy wire braces through remote experiment was effectively demonstrated.
- Magneto-Rheological Fluid may be difficult for some students to understand, but it was shown that students can learn Magneto-Rheological Fluid through remote experimentation.
- Demonstrating damping adjustment using Magneto-Rheological Fluid material with this remote experiment was shown to be effective.
- Vibration control using Magneto-Rheological Fluid demonstrated by remote experiment is effective.
- Smart material can be effectively demonstrated and understood by students through remote experimentation.
- The graphical user interface for the remote experiment is user-friendly.
- Remote experimentation to assist students learning is effective overall.
- Students express desire to participate in remote experiments in future classes.

As the above survey results illustrated, the remote laboratory platform based on the novel unified framework provided a more effective way for teaching ME courses. Through the vivid remote experiments interface, student performance and output of ME course learning objectives were enhanced.

CONTRIBUTIONS AND IMPROVEMENTS

As shown in Table 3, through this research project, three challenges for remote laboratory development have been solved or improved.

Table 3. Solved and Improved Challenges.

	Solved and Improved Challenges
I	Remote laboratory system cross-platform performance and the client side software without plug-in issue (solved).
II	The real-time experiment data and real-time experiment video traversing network firewall transmission issues (solved).
III	The remote laboratory system security issue (improved).

- To improve Challenge I, a novel unified framework was proposed for implementing the remote laboratory without the need of an extra plug-in. The user interface can be run on most popular Internet browsers in any platform without installing any additional plug-in. The capability of running remote experiments on portable devices allowed users to gain insights by observing and interacting with the real instrument in an efficient way.
- To resolve Challenge II, two innovative solutions were proposed for remote laboratory development to solve the real-time experimental video and real-time experimental data transmission across network firewall issues.
- To improve Challenge III, the new isolated experiment network and the authentication URL were designed to improve the remote laboratory system security issues. These solutions were implemented in the remote laboratory.

FUTURE WORKS

While the novel remote experiment solution, compared with traditional solutions used previously, has been significantly improved, more development must be done to improve the remote laboratory system stability and security. Future development tasks are listed as follows:

- Based on the current solution of Challenge I above, the Microsoft IE browser cannot support MJPEG real-time video format very well. To solve the video display problem in Microsoft IE browser, users will have to install the Java applet plug-in for the video display. Considering the speed of software technology development, it is believed this problem can be resolved in near future.
- Based on the current solution of Challenge III, encrypted URL authentication is used with the MD5 encryption and a decryption algorithm to resolve authentication URL issues. A ten-second timer is used to control URL authentication effectiveness, but its stability needs to be improved in future work.

CONCLUSIONS

In this paper, a remote laboratory based on a novel unified framework was presented. Two remote experiments, SMA and SVP, were successfully implemented under this novel unified framework. The real-time experimental video and real-time experimental control command and data transmission across network firewall issues were successfully resolved through two innovative solutions proposed for remote experiment development. With the new remote laboratory solution enabled by the novel unified framework, users can operate or view the real-time remote experiments on most popular web browsers without firewall issues or the need for third party plug-ins. The remote laboratory has successfully been used for teaching purposes and, through a satisfaction survey of students in a pilot remote experiment, the new remote laboratory was shown to be effective in student understanding of course objectives. The capability of running remote experiments on portable devices permitted users to gain insights through observing and interacting with the real instrument in a more flexible way. This research project will improve future teaching and learning activities as well as significantly benefit remote laboratory development.

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Bibliography

1. Kist, A. A., Gibbings, P., Maxwell, A. D., & Jolly, H. (2013). "Supporting remote laboratory activities at an institutional level". International Journal of Online Engineering (iJOE), 9(S5), pp-38.
2. Gomes, L., & Zubía, J. G. (2008). "Advances on remote laboratories and e-learning experiences". Engineering (6), University of Deusto Publications.
3.Gustavsson, I., Nilsson, K., Zackrisson, J., Garcia-Zubia, J., Hernandez-Jayo, U., Nafalski, A. Hkansson, L. (2009). On objectives of instructional laboratories, individual assessment, and use of collaborative remote laboratories. Learning Technologies, IEEE Transactions on, 2(4), 263-274.
4. Abdulwahed, M., & Nagy, Z. K. (2013). Developing the TriLab, a triple access mode (hands-on, virtual, remote) laboratory, of a process control rig using LabVIEW and Joomla. Computer Applications in Engineering Education, 21(4), 614-626.
5. Barrios, A., Panche, S., Duque, M., Grisales, V. H., Prieto, F., Villa, J. L. & Canu, M. (2013). A multi-user remote academic laboratory system. Computers & Education, 62, 111-122.
6. Harward, V. J., Del Alamo, J. A., Lerman, S. R., Bailey, P. H., Carpenter, J., DeLong, K., Felknor, C., Hardison, J., Harrison, B., Jabbour, I., Long, P.D., Mao, T., Naamani, L., Northridge, J., Schulz, M., Talavera, D., Varadharajan, C., Wang, S., Yehia, K., Rabih Zbib, & Zych, D. (2008). The iLab shared architecture: A Web Services infrastructure to build communities of Internet accessible laboratories. Proceedings of the IEEE, 96(6), 931-950.
7. Orduña, P., Irurzun, J., Rodriguez-Gil, L., Zubía, J. G., Gazzola, F., & López-de-Ipiña, D. (2011). Adding New Features to New and Existing Remote Experiments through their Integration in WebLab-Deusto. iJOE, 7(S2), 33-39.
8. Zubía, J. G., & Alves, G. R. (2011). "Using Remote Labs in Education - Two Little Ducks in Remote Experimentation". Engineering (8), University of Deusto Publications.
9. Mateos, V., Gallardo, A., Richter, T., Bellido, L., Debicki, P., & Villagrá, V. (2012). "Lila booking system: Architecture and conceptual model of a rig booking system for on-line laboratories". International Journal of Online Engineering (iJOE), 7(4), 26-35.

10. Olmi, C., Cao, B., Chen, X., & Song, G. (2011). "A Unified Framework for Remote Laboratory Experiments". In Proceedings of the 2011 ASEE Annual Conference & Exposition.
11. Chen, X., Zhang, Y., Darayan, S., Kehinde, L., Olowokere, D., & Osakue, D. (2011). "Using Virtual and Remote Laboratory to Enhance Engineering Technology Education". In Proc., ASEE Annual Conference & Exposition.
12. Gomes, L. & Bosgoyan, S. (2009). "Current trends in remote laboratories", IEEE. Trans. on Industrial Electronics, 56(12), pp. 4744-4756, December, ISSN: 0278-0046.
13. Rodriguez-Andina, J., Gomes, L. & Bogosyan, S. (2010). "Current trends in industrial electronics education", IEEE. Trans. on Industrial Electronics, 57(10), 3242-3244, October, ISSN: 0278-0046.
14. Hughes-Croucher, Tom & Wilson, Mike (2012), "Up and Running with Node.js (First ed.)", O'Reilly Media, p. 204, ISBN 978-1-4493-9858-3
15. Herron, D., (2013). "Node Web Development, Second Edition", Packt Publishing, ISBN 184951514X, Jul 19, 2013.
16. Rai, R., (2013). "Socket.IO Real-time Web Application Development", O'Reilly Media, ISBN 178-2-1607-87, February, 2013.
17. Wang, N., Chen, X., Song, G., & Parsaei, H. (2015). "A Novel Real-time Video Transmission Approach for Remote Laboratory Development," International Journal of Online Engineering, 11(1), 4-9.
18. Wang, N., Chen, X., Song, G., & Parsaei, H. (2015). "Using Node-HTTP-Proxy for Remote Experiment Data Transmission Traversing Firewall," International Journal of Online Engineering, 11(2), 60-67.