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Development of Web-Based Experiments for Undergraduate Mechatronics Education*

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In engineering education practical experiments is very important for each student, but due to the limitation of time and available resources such as laboratory equipment, space and instructors enough hands-on real experiments could not be provided to all students enrolled in the program throughout the academic year. In this sense web-based remote experiments through internet become a solution for engineering education and an emerging new paradigm for students and teachers. This paper presents the development of the web-based remote vibration experiment system for mechatronics education. Students can access this experimental equipment through an internet and conduct vibration experiment remotely without any restriction on time and place. IP address for data communication and web-service are assigned in local computer and then students receive experimental results and the captured pictures using network. The developed system provides real-time feedback of the tested results. Ubiquitous access to the system gained popularity from students.

Keywords : Mechatronics education, Web-based remote experiment, Vibration, Ubiquitous access

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Introduction

The rapid development of Information Technology (IT) offers a serious and vital challenge to the traditional engineering fields. In particular, programming, control, and web technology present unlimited benefits in the development of new products and systems.

Various efficient systems, such as safety diagnosis systems and remote-maintenance systems can be constructed by applying remote measurement equipment (Kwak, 2000; Shim et al., 2004), thereby we get decreasing time and expenses, as there is no need for site visits. In addition to that, if such systems are applied to manufacturing, all the manufacturing and quality processes can be monitored in central station (Selmer et al., 2007; Wang et al, 2012). In the future, it is inevitable that more remote control and remote measurement systems will be developed based on the web, and if such systems become standardized and commercialized, a ubiquitous system, totally different from the traditional way, can be used for remote control, along with a telemeter that is unlimited by time or place (Hites, 2002; Ok et al., 2000; Sanchez et al., 2002).

As the internet develops, the increasing availability of new video, text, and multimedia services are also attracting attention to such web applications as bidirectional remote-conferencing and remote supervision systems (Rohrig & Jochheim, 2001). In education the internet also provides a variety of methodologies for enhancing the experience of learning as well as expanding educational opportunities. Integration of the internet with educational systems is well described in Prindexter and Heck(1999)'s work.

In engineering education practical experience is very important for each student, but due to the limitation of time and available resources such as laboratory equipment, space and instructors enough hands-on real experiments could not provided to all students enrolled in the program throughout the academic year. In reality hands-on real experiments in engineering curriculum were only possible in well-equipped laboratories and universities.

Now engineering experiments are facing change and thus web-based remote experiments through internet become a solution for engineering education and an emerging new paradigm for students and teachers.

Several universities are currently starting to build systems for web-based remote experiments in the field of engineering education. Purdue University has provided a virtual laboratory called SoftLab for physical experiments and numerical simulation. (Catlin et al., 2000) Oregon State University have developed an innovative real-time remote-access control engineering teaching laboratory system called SBBT (Second Best to Being There) that enable students to control a 3 degree of freedom robot arm remotely (Aktan et al., 1996). National University of Singapore developed web-based virtual laboratory on a frequency modulation experiment for undergraduate teaching (Ko et al., 2001). Also MIT is managing online laboratories, iLabs, to share expansive equipment associated with lab experiment (http://icampus.mit.edu/ilabs).

Using these web-based remote experiments students can remotely access to laboratory equipment and be able to perform experiments in real-time through the internet at any time and place, also laboratory reports can then be sent using electronic mail (Levesly et al., 2006; http://weblabs.cheng.cam.ac.uk /control.html).

In mechatronics engineering curriculum of undergraduate course students learn the design (modeling, analysis and measurement), actuation and control of a mechanical system under combination of theory and practice in class. For example, control of vibrating mechanical system is one typical example of mechatronics course in undergraduate. In order to control the motion of a mechanical system such as robot arm information for dynamic characteristics of robot arm obtained by measuring natural frequency and damping ratio etc. – are prerequisite. However, these kinds of web-based experiments are still limited and are in progress.

In this paper, we have developed a web-based remote vibration experiment system for mechatronics education. Any user enrolled in the vibration class can freely access this experiment system using the internet and remotely conduct a vibration experiment at any time and place. This is an example of combination of information technology and mechatronics education and can be used as a method of e-learning and self-learning for students.

Remote Vibration Experiment System

Interfacing hardware and software

The outline of web-based remote vibration experiment system constructed for this purpose is shown in Figure 1. The experiment system, shown in Figure 2, is composed of students' remote computer (known as client PCs) used to access the experiment system through the internet, local computer (called a server PC) for data acquisition and control, and also experiment system consisting of cantilever beam with strain gauges and Misumi fixed type shock damper of constant damping coefficient, an electromagnet for applying an initial deflection to the beam, a web camera for recording and capturing real-time motion of the beam.

To facilitate the web-based control and remote measurement of vibration experiment, National Instrument (NI) I/O cards were taken as the system hardware for data acquisition and control. National Instrument's LabView software was also chosen for the purpose. This software supports a flow chart concept familiar to engineers instead of complex text-based coding for programming. The I/O interface card used for these experiments is NI 9263 which has 4 analog output channels of 16-bit resolution.

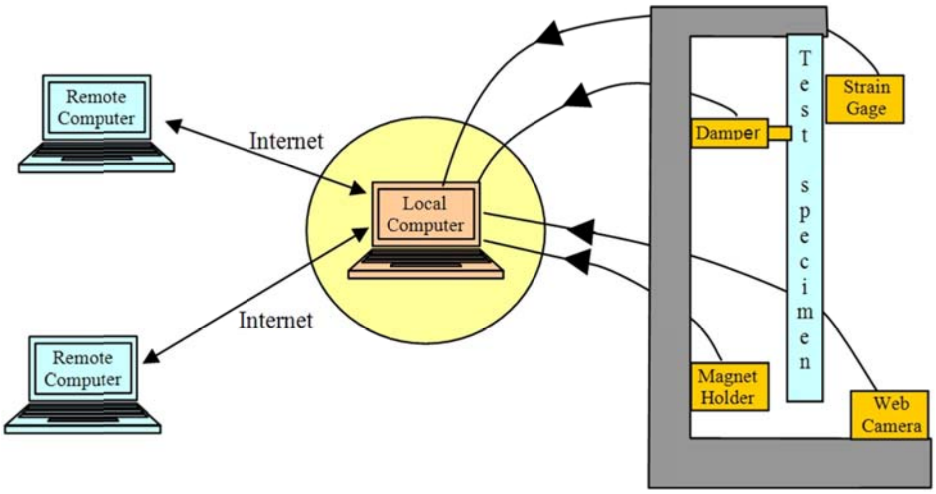

Figure 1. Schematic view of Web-based remote vibration experiment

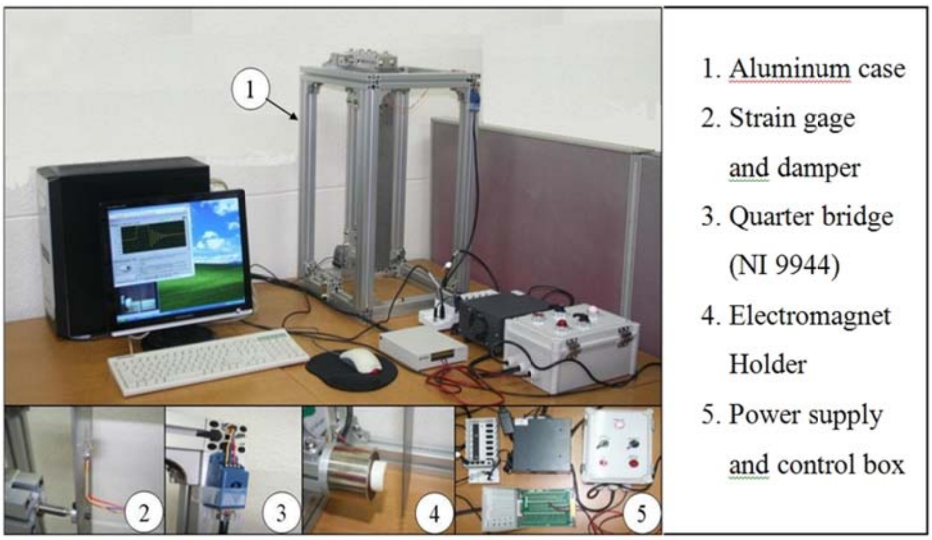

Figure 2. Implementation of remote vibration experiment system

A wiring diagram created by LabView for this purpose is shown in Figure 3. To embody each module to be operated by LabView on the web environment, the whole program should be converted into HTML(Hypertext markup language).

LabView supports a function to automatically convert the completed program into HTML. By using the HTML file saved by LabView and the IP address assigned to a local computer, anyone can access to this remote vibration computer. Test specimen for this vibration system is a plate shape with 600 mm in length and 60mm in width, shown in Figure 4, and is rigidly fixed at the top by bolt to the aluminum case. In case of aluminum specimen, a thin steel plate needs to be attached at the bottom of specimen.

A strain gage (KFEL-2-120-C1 by Kyowa, Japan) to measure the vibration characteristics of specimens and a fixed type shock damper (Musumi, Japan) in which its damping forces can be adjusted manually by turning end knob to attenuate the vibration are attached on the specimen. To detect and transfer the resistance coming out of the strain gage, we construct quarter bridge with NI 9944 Quarter bridge and NI 9237 module. The voltage drop caused by the bridge is also a source for a gain error, so the NI 9237 compensates this error. We applied 10 Hz lowpass filter of LabView function to eliminate any measuring noise from the strain gage.

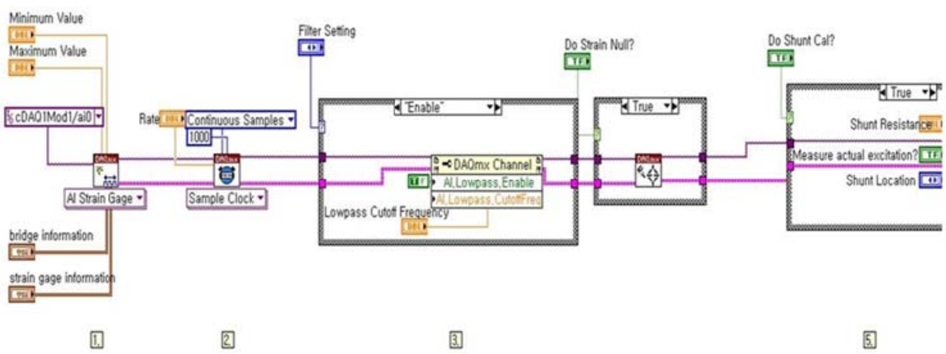

Figure 3. Wiring diagram of LabView for vibration experiment

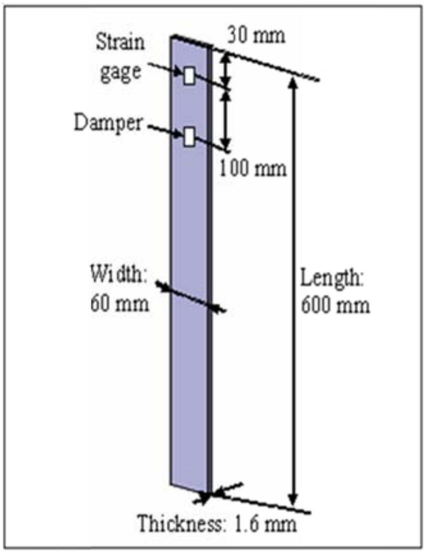

Figure 4. Test specimen

Specimen 1	1.6	Steel
Specimen 2	2.0	Steel
Specimen 3	3.5	Aluminum

Performing experiment via internet

Remote experiment is performed in two stages. First students connect local computer through the internet using students' remote computer, whenever contact is made, user authentication of remote computer is required. This request can be automatically approved by the local computer, or approval can be done manually. Connection approval is used to prevent overstrain of the equipment or breakdown due to excessive connections. If someone is connecting the system already, no other user can connect at the same time, so the other users have to wait till current user's experiment is over.

An electromagnet holder, power supply (JWS 600-48), a remote voltage controller (NI PCI-6221) on the local computer's board and control box connection tool (NI SCB-68) are prepared and installed in advance. The cathode is connected to No. 18 (DGND) in NI SCB-68 and the anode is connected to No. 52 (DIO0) in SCB-68.

To activate the vibration of test specimen, the bottom of the specimen fixed at the top end is displaced to a designed initial position by an electromagnet holder and suddenly released it to allow the specimen to vibrate. If the specimen is composed of nonferrous metals, such as aluminum and magnesium, a thin steel plate that can form magnetic fields, needs to be attached to the bottom of the specimen to allow for remote functioning.

In the second stage, a web camera captures the real-time motion of specimen and a Microsoft windows media encoder to transfer the real time image of specimen to the remote user via Internet. The use of the one-on-one TCP/IP correspondent method makes it possible to communicate with a remote user, regardless of time and place. The remote users can operate the vibration system and see its results from their home.

In details, the LabView screen consists of a vibration graph and icons that drive the electromagnet, shown in Figure 5. The measurement of vibration characteristics via time-vibration amplitude curve as shown in Figure 5 starts when the start

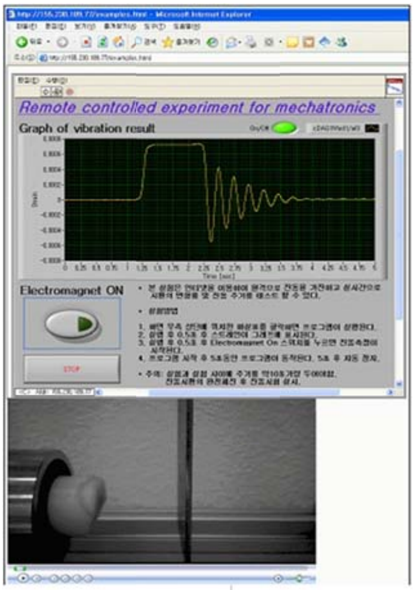

Figure 5. Remote user's screen

button at the top is clicked. After the experiment starts, pushing on the operation button of the electromagnet creates magnetic force on the specimen, and forces the specimen to be attached on electromagnet for 1 second and then releases it to be vibrated. The experiment is executed for 5 seconds, and the clip at the bottom of the screen allows the remote users to monitor the state of the experiment.

Students can access to the local computer IP address (http://155.230.189.77/examples.html) at Kyungpook National University. The LabView setup file LVRunTimeEng.exe should be operated before continuing with the experiment via the Internet. When student access to this site to perform some experiment the first time, this setup file will be downloaded automatically from the local computer and saved in their computers. After this setup process, student computer will be rebooted automatically. Once rebooted, access to this site again and there will be the pop-up window, Figure 5, in which student can operate the vibration system remotely.

Figure 6 shows the result of vibration experiment evaluated from the response of strain gauge. The measured data from the strain gage is similar to the 1st mode of vibration of test specimen. So the experiment system in this paper is equivalent to the free vibration of a damped spring-mass system in Figure 7. From the measured data in Figure 6 and analytical equations shown in Figure 7, the system data such as damping ratio, damped natural frequency can be calculated as follows.

In this study we have chosen three different specimens with different thickness and material to clarify the effect of those differences on vibration characteristics such as natural frequencies. The calculated data of the system are in Table 1.

The validity of the web-based remote experimental data can be assured by comparing the calculated data of Table 1 with ANSYS simulation data. From modal analyses of ANSYS workbench (V.14.0) we obtain 24.5Hz for 1.6mm steel plate, 30.63Hz for 2.0 mm steel plate, and 49.9Hz for 3.5mm aluminum plate as natural frequency which are reasonably matched with the experimental data, 28.07Hz, 30.0Hz, and 43.5Hz respectively. The difference may come from the position of strain gauge.

From this remote vibration experiment system student can freely access from their location and perform tests to study the vibration characteristics of each material of machine system by reminding the basic theory of vibration.

In this system we adopted the damper with a constant damping coefficient instead of Magneto-Rheological (MR) fluid damper. By installation of MR damper students can change the damping coefficient by remotely adjusting the electric current to actively control the vibration of the system and performing the experiment for their purpose. If the result of experiments does not meet their goal of experiments, they can modify the damping coefficient and repeat the experiment again.

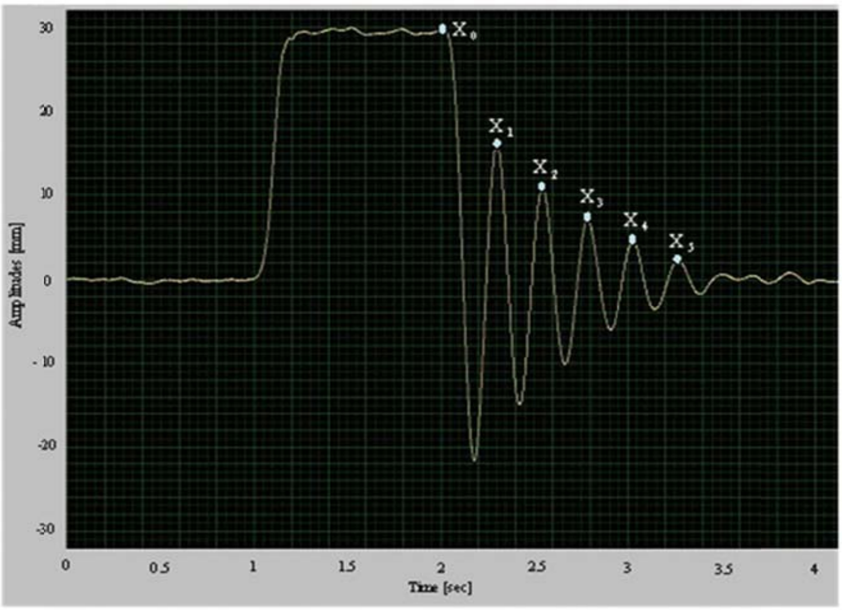

Figure 6. Response of strain gage

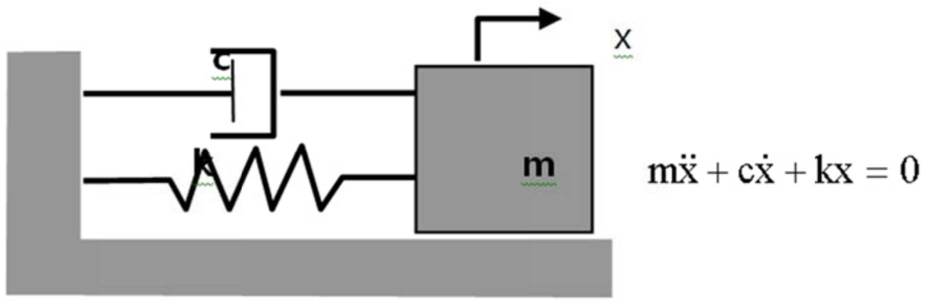

Figure 7. Damped spring-mass system

Table 1. Calculated data of the system

Name	Symbol	Formula	Specimen 1	Specimen 2	Specimen 3
Period of vibration	T_d	$t_2 - t_1$	0.23	0.21	0.15
Ratio of successive amplitudes	δ	$\ln(X_i / X_{i+1})$	0.64	0.48	0.61
Damping ratio	ζ	$0.5 * \delta / \pi$	0.101	0.076	0.096
Natural frequency	$\omega_n(Hz)$	$2\pi/(T_d\sqrt{1-\zeta^2})$	28.07	30.00	43.5
Damped natural frequency	$\omega_d(Hz)$	$\omega_n\sqrt{1-\zeta^2}$	27.93	29.92	43.3

Conclusions

We have developed the remote vibration experiment system which can be operated by remote user via internet. This remote vibration experiment system is composed of various modules, such as data acquisition, control, data communication application, and real-time picture which are controlled by LabView. We converted the whole program into the HTML file using LabView to allow the remote user to access this system directly without time and space limitations.

This research prepared a foundation to solve the some problems that many universities may have related to on-the-spot experiments due to lack of space. The new technology used to construct a remote vibration experiment system is expected to provide an alternative solution to the problems for some universities with limited experimental resources. And the remote experiment and telemetering technology confirmed by this research can be applied to various industrial fields. In particular, future-oriented projects, such as home-automation will enrich the quality of human life.

However, the current average network speed is not adequate to produce motion data in real time. Thus, a real-time picture transfer algorithm needs to be developed. And further studies about applying some kind of the adjustable damper i.e. MR damper to characterize the effect of experiment variables and to help the student's understanding regarding the mechatronics system are still needed.

To set up the web-based remote experiment system in mechatronics curriculum in undergraduate course this work is in progress. The results of student evaluation for this remote vibration experiment will be reported in further study.

In conclusion, the developed web-based remote vibration experiment helps students gain the same experience as with performing experiment in the real laboratory. Moreover, the use of web-based remote experiment opens a new arena for engineering experiments that previously were only possible in well-equipped laboratories.

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