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Use of Robotic Controls in Ergonomics Laboratories

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USE OF ROBOTIC CONTROLS IN ERGONOMICS LABORATORIES

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SUMMARY: International collaboration in teaching and research has expanded as a result of the widespread accessibility and use of the World Wide Web. While on-line education has experienced the greatest growth, the use of remote laboratories in research and teaching is relatively new. The development of a remote ergonomics laboratory using a new Internet technology is described. The purpose of the remote laboratory is to provide international access to an advanced thermal manikin technology which provides a platform for measuring the thermodynamic properties of protective clothing during exposure to controlled environmental conditions. To date, the laboratory has generated global interest and promoted international collaboration in ergonomics teaching and research.

Key words: *robotic control, laboratory, ergonomy*

INTRODUCTION

Rapid expansion of Internet use and its growing popularity as a social media tool has impacted communication and education worldwide in a positive way. The technology also offers new opportunities in engineering and science education and provides new avenues for teaching through interactive experimentation and simulation *(Selmer, Kraft, Moros, and Colton, 2007)*. Broadband availability in conjunction with data compression programs make quality audio and video streaming of lectures on the Internet possible. Computer and Internet based learning has now become an important part of education internationally. A special challenge for online education in the engineering, science, and technology fields, however, is how to include the traditional hands-on laboratory settings through the Internet. Hands-on laboratories have been an integral part of most human factors and ergonomics education in the past *(Feisel and Rosa, 2005)*. Concepts presented in lectures are usually complemented with laboratory experimentation. Traditionally, hands-on education has been considered the "backbone" of engineering and science education which allows students to conduct practical experiments, allows students to observe dynamic phenomena in real-time, allows students to test hypotheses, allows students to learn from their mistakes, and offers students the opportunity to reach their own conclusions *(Tompkins and Pingen, 2002)*. With the rapid advances in microprocessor and communication technologies, more and more equipment can now be reconfigured and controlled remotely. This development has made hands-on training via the internet possible. Currently, there are two approaches to conducting laboratory exercises online. These include virtual labs and remote labs. The virtual laboratories are based on software that simulates the laboratory environment only. They are especially useful when equipment is too expensive, unsafe, or unavailable for use by students. Virtual laboratories, on the other hand,

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allow students to repeat an experiment multiple times, giving them the chance to see how changed parameters and settings can affect the outcome. Since the virtual laboratory exists only in the computer, students can learn safely from failures without causing physical damage. Remote laboratories, however, are actual physical facilities used to conduct experiments and, when not used properly, may cause damage or harm. Such facilities are controlled remotely in real-time through the Internet. The experiments use actual equipment and actual instruments. However, they are located at a different place from where they are being controlled.

To promote student access to hands-on learning in the field of ergonomics and human factors engineering, not only at the local level but also regionally and internationally, an existing thermal manikin laboratory at Boise State University was reconfigured to accommodate the Internet-based remote control technology. The laboratory now serves as an educational platform for academic partner institutions regionally and internationally.

THE LABORATORY

The Ergonomics Laboratory is equipped with a thermal manikin system capable of assessing the heat exchange characteristics of protective clothing worn under controlled environmental conditions. Equipment includes a manikin air pressure system, manikin air heating system, environmental ventilators, infrared radiators, and digital thermometers measuring manikin input and output temperatures needed to compute the manikin heat gain or heat loss.

IT Issues

Before the facility became suitable for use as a remote laboratory, the IT infrastructure for the remote connections had to be resolved. Issues relating to network firewall policies and the selection of appropriate software providing the connection and interface needed to be agreed upon also prior to start-up.

Training

Initiating a remote laboratory experiment always requires a support staff. Furthermore, students and researchers must be fully aware of the experimental procedures, must be knowledgeable in using the remote controls properly and safely, and must be aware of the time requirements associated with collecting accurate data. This can be achieved through in-house training.

Outcome Assessment

Assessing the learning outcome or value of the remote laboratory assignments requires the collection and evaluation of feedback from the student users. This information should be used to correct deficiencies and should be used to modify the laboratory experience. Use of a remote laboratory presents an on-going learning and revision process for the laboratory sponsors as well as for the laboratory users.

ROBOTIC CONTROLS

The Internet platform serving the Remote Laboratory at Boise State University is provided by Apriori, LLC through its “Reach-In” browser technology. This system allows novice Internet users, i.e. users with no special computer skills, the ability to control mechanical devices through the internet using their computer and their home Internet connections. This functionality is possible in any geographical location in the world that has Internet access.

Technology Advantages

The technology platform provides opportunities for long-distance international remote laboratory use in the following ways:

- The software reduces latency to less than 1 second which makes it suitable for visual control of the instruments and equipment.
- The software works in all major browsers without the need for special downloads.
- The software can control any hardware component over the web.
- The technology allows many users to interact on one site without compromising the quality for the user in control.
- A queuing methodology allows for global users to join a queue from anywhere on the Internet.

A student or researcher with sufficient connection speed can log onto the remote laboratory website and control all of the assigned laboratory devices from anywhere in the world. The user has the ability to control a camera, pan up and down, and zoom in and out on every instrument located in the laboratory. At a click of their mouse, a user can control multiple mechanical devices at any one time. The laboratory remote control schematic illustrating the relationship between the key components and the sub-systems of the laboratory are illustrated in Figure 1.

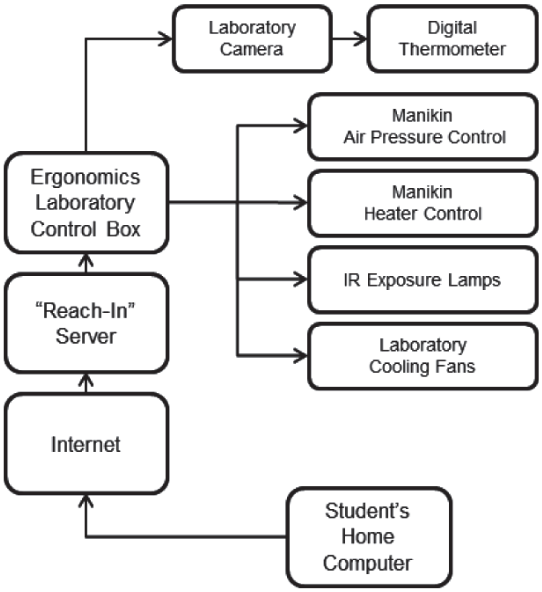

Figure 1. Layout for of the laboratory remote control system

Slika 1. Organizacija laboratorijskog sustava na daljinsko upravljanje

SYSTEM FEATURES

The key feature of this system lies in its architecture which minimizes the latency time of the hardware components and the latency of the software that controls all of the devices. A main server acts as a "hub" for all information transfer. A dedicated replication server is included that handles the video stream separately since the video stream represents the largest amount of data transfer. A camera is connected to an on-site control box. The mechanical devices in the laboratory are connected to motherboard located inside the control box which converts the digital data signals into voltage outputs. The voltage outputs act as the driving force to articulate the geared camera hardware back and forth, up and down, on, and of, etc. A kernel of software is located on the control box that communicates with the main servers providing an "IsAlive" beacon. Service technicians can respond if the "IsAlive" beacon does not check-in within 15 seconds.

LABORATORY USE

The ergonomics laboratory contains an inflatable thermal manikin system designed to measure the heat transfer characteristics of clothing systems. The technical design features are illustrated in Figure 2. While the manikin needs to be clothed by a staff member, all controls required to operate the system can be manipulated remotely via the Internet. A student, or a researcher, logs on to the laboratory website and sees the laboratory "live" through a camera that is in the "ON" position 24/7 i.e. all the time. The camera is illustrated in Figure 3. The user can engage the manikin sub systems consisting of the manikin air pressure system and the manikin internal air heating system activated through by the power control relays as shown is Figure 4. This provides the "start-up" operating configuration for the manikin. The manikin must reach thermal equilibrium with the laboratory environment prior to testing. The user can then operate the laboratory IR exposure lamps and the laboratory cooling fans to change the manikin exposure conditions. Using the camera's directional controls and the "zoom" feature, the user can monitor the digital thermometers that display the manikin input air temperature as well as the manikin output air temperature as illustrated in Figure 5. The temperature values are then used to calculate the heat loss or heat gain exhibited by the manikin during exposure to the various environmental conditions and / or clothing configurations.

CONDUCTING AN EXPERIMENT

To determine the heat transfer characteristics of a garment requires the student or researcher to perform two measurement procedures sequentially by using the following steps which are illustrated schematically in Figure 6:

- The thermal manikin must first reach thermal equilibrium in a "semi-nude" configuration (wearing short pants only). This serves as the "control" configuration as illustrated in Figure 7A.
- The temperature difference between output air and input air is then observed and recorded and subsequently entered into a standard energy loss calculation (formula).
- Once thermal equilibrium is reached, heat radiation exposures or wind conditions can be added. Again, the manikin input and output temperature values are recorded at equilibrium.
- To measure the thermal characteristics of clothing systems, the procedures used for the "control" conditions are repeated with the exception that the manikin is now clothed as shown in Figure 7B. The energy loss values are then compared to the "control" conditions. This provides values for the thermal properties of the clothing system being tested under the selected environmental exposure conditions.

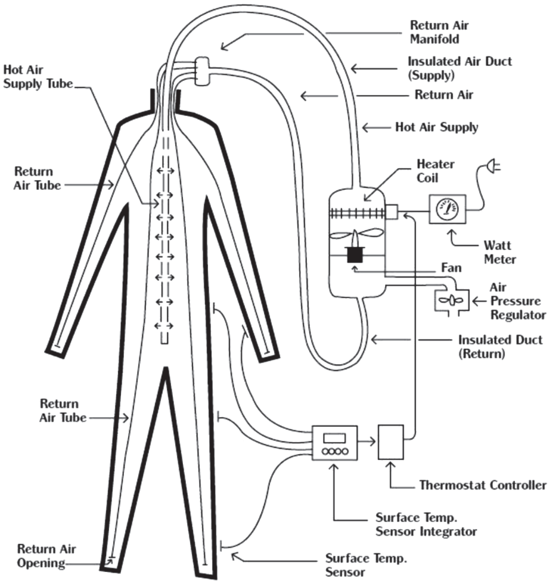

Figure 2. Illustration of inflatable thermal manikin system used in the remote laboratory

Slika 2. Prikaz sustava manekena na termalno napuhavanje u daljinski upravljanom laboratoriju

Figure 3. Remote controlled internet camera allowing un-interrupted visual access to the laboratory

Slika 3. Internetska kamera na daljinsko upravljanje koja omogućava neprekidan vizualni pristup laboratoriju

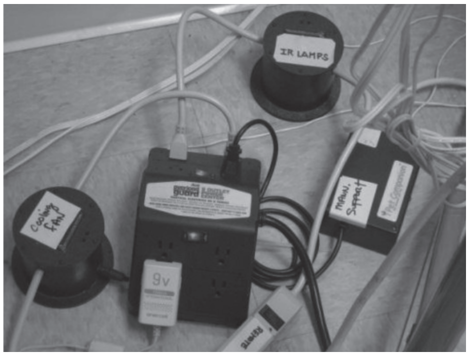

Figure 4. Remote control relays used in activating thermal manikin sub-systems

Slika 4. Releji daljinskog upravljanja za aktiviranje podsustava termalnih manekena

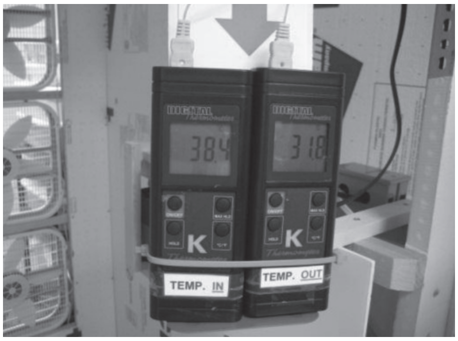

Figure 5. Temperature monitors showing manikin input air temperature and manikin output air temperature values which are needed to compute manikin heat loss values

Slika 5. Monitori temperature prikazuju vrijednosti temperature ulaznog i izlaznog zraka kod manekena potrebne za izračun vrijednosti gubitka topline manekena

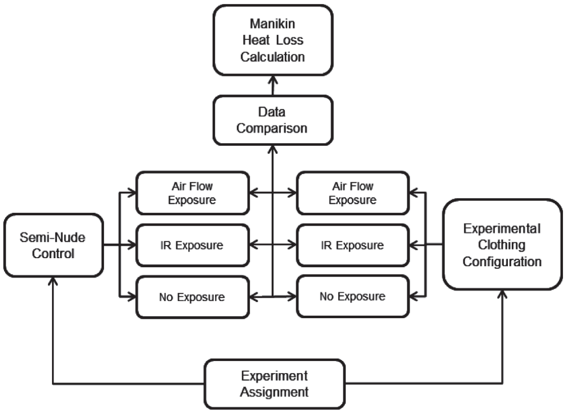

Figure 6. Schematic of Test protocol

Slika 6. Shematski prikaz ispitnog protokola

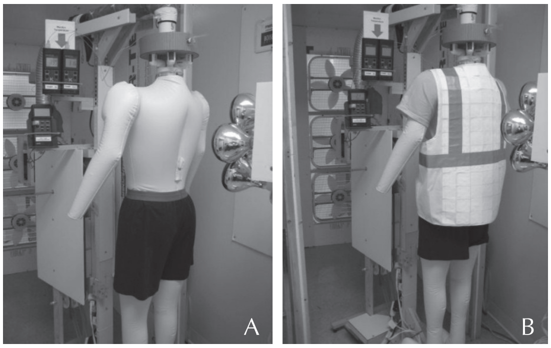

Figure 7. Illustration of thermal manikin in a semi-nude "Control" configuration (A) and in the "Experimental" configuration (B)

Slika 7. Prikaz termalnog manekena u polugoloj 'kontrolnoj' konfiguraciji (A) i u 'eksperimentalnoj' konfiguraciji (B)

ACCESSING THE LABORATORY

Access to the remote thermal laboratory is currently open to the global Internet community. Visitors are permitted to operate the equipment "at-will" to observe the technical functions of the key manikin equipment. User tracking has shown that persons from all continents around the world have accessed the facility either as a viewer or as an active "player" operating the various manikin sub-systems. Although the current features appear to offer visitors a video-game "entertainment" opportunity, the goal of the open access policy is to promote interest in ergonomics research. However, when experiments are being conducted locally or "in-house", the remote controls are disabled. This allows the researchers to eliminate outside interference or interruptions. However, the camera continues to remain "on" during experiments which allows visitors anywhere in the world to view these activities 24/7. The current URL for this remote laboratory website is: http://www.reach-in.com/demos/conduct-an-experiment.

COLLABORATION

International use of the remote thermal manikin laboratory as a research facility developed after visiting researchers successfully conducted in-house studies using the thermal manikin technology and wanted to continue with their experiments after returning home *(Reischl, Mijović, Skenderi & Čubrić, 2010, Reischl, Goonetilleke, Mijović, Skenderi, 2011, Reischl and Goonetilleke, 2011)*. The collaborations have expanded from Boise State University in the USA to the University of Zagreb in Croatia and the Hong Kong University of Science and Technology. Collaborations are being explored with universities in Central and South America. Although the advantage of using the remote laboratory increases with distance, differences in the East-West time-zones can make real-time communications regarding experimental problems and set-up requirements difficult. Nevertheless, as academic resources become scarcer, collaborative use of laboratory resources locally, regionally, and internationally will be helpful. Remote laboratories will undoubtedly play an important role in promoting collaboration in education and research in the future.

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UPORABA ROBOTIKE U LABORATORIJIMA ZA ERGONOMIJU

SAŽETAK: Međunarodna suradnja u nastavi i istraživanjima porasla je kao rezultat raširenosti i dostupnosti globalne mreže. Iako je primjena e-obrazovanja iznimno porasla, uporaba daljinskih laboratorija u istraživanju i nastavi relativno je nova. Opisan je razvoj daljinskog ergonomijskog laboratorija pomoću internetske tehnologije. Svrha daljinskog laboratorija jest da se diljem svijeta omogući pristup naprednoj tehnologiji manekena na termalno napuhavanje koja nudi temelj za mjerenje termodinamičkih svojstava zaštitne odjeće tijekom izlaganja kontroliranim uvjetima okoline. Laboratorij je izazvao opće zanimanje te promiče međunarodnu suradnju na području nastave i istraživanja u ergonomiji.

Ključne riječi: *robotičko upravljanje, laboratorij, ergonomija*

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