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WIP: Biomedical Sensors Laboratory Activities Using Labview and Adaptation for Virtual Instruction

Prof. Benjamin Hawkins, California Polytechnic State University, San Luis Obispo

My professional interests focus on the development and use of microsystems (biosensors, microcontrollers, etc) to matters of human health. Primarily this is focused on microfluidics, but also ranges from wearable devices to laboratory equipment. Applications range from cell measurements to ecological questions. Educationally, I am focused on developing courses and content that connects theory to technology in practice, with an emphasis on rigorous understanding of both.

Work in Progress: Biomedical Sensors Laboratory Activities Using LabVIEW and Adaptation for Virtual Instruction

Introduction

Biomedical Engineering (BMED) practice often reflects a "systems engineering" perspective on electrical and/or mechanical devices or systems that interact with a biological sample. The successful Biomedical Engineer understands the breadth of physics and physiology involved in the design and testing of a new system. Across subdisciplines within the field, there is a need to understand and quantitatively describe and evaluate measurement systems. An engineering approach to biomedical systems will almost always involve and require the ability to collect data and accurately interpret it in the context of relevant system physiology. The Master of Science (MS) program in BMED at Cal Poly, San Luis Obispo involves a core curriculum that focuses on the collection and application of data in a three-part sequence: data collection, statistical data analysis, and data-driven modeling. The goal of this sequence is to provide a foundational skill set that is immediately applicable to any chosen subdiscipline within BMED.

The first course in this sequence is BMED 505: Biomedical Signal Transduction and Data Acquisition and includes a laboratory component to offer students a hands-on opportunity to not only engage in building a sensor and collecting data, but critically examining them and evaluating their performance in the context of the desired measurement. A sequence of laboratory activities was developed that uses LabVIEW to acquire thermal, electrical, mechanical, and optical data for biomedical applications. In order to accommodate the need for virtual instruction imposed by the COVID-19 pandemic (and potentially for future implementation), the hands-on circuit building, sensor assembly, and data collection portions of the lab were performed by the instructor as part of a synchronous virtual demonstration. Students were then tasked with creating a LabVIEW program to read in and process instructor provided datasets during the main laboratory session. After successfully reading in and processing data, students are tasked with analyzing the data to extract both useful signal information and sensor figures of merit (e.g., resolution, limit of detection, sensitivity, etc.).

Background

A sequence of laboratory activities develops students' core skills in programming using the LabVIEW interface, with progressively more difficult and challenging applications. The structure of each laboratory activity centers around the implementation and testing of one or more sensors that collect a specific type of data (e.g., force, temperature, electric potential, etc.). LabVIEW is a graphical programming environment where functional blocks are placed representing functions or operations to be performed on a set of inputs to produce an output. In addition to LabVIEW programming language, National Instruments provides a wide array of companion hardware for interfacing and data acquisition. This course makes use of the Engineering Laboratory Virtual Instrument Suite (ELVIS) hardware platform, that provides analog and digital inputs and outputs for controlling, stimulating, and measuring circuit values. The ELVIS III platform runs an onboard FPGA, meaning that it behaves as an independent system rather than a peripheral. This shifts the typical paradigm of communication between a LabVIEW VI running on a desktop computer and a data acquisition device from direct control to a peer-to-peer format. In theory, this would allow for hardware and embedded software to run on the ELVIS III independent of a connected computer or potentially to communicate acquired data to a networked computer. For the purposes of this lab, however, we wish to control the ELVIS III instruments from student coded VIs, so we develop a USB communication bus and subVI for using student written VIs to control onboard oscilloscope, function generator, voltage source, and analog/digital IO functions on the ELVIS III and communicate data to the student VI for observation, analysis, and collection.

Laboratory Activities

Each laboratory activity is structured around a three-part process of “Demonstration”, “Apply”, and “Extend” wherein students are aided through the initial development process and setup of the basic laboratory experiment. As an example, for the first lab students are tasked with setup, implementation, and characterization of two different force sensors for ballistocardiography (BCG) measurement. A force sensitive resistor and a micro-load cell are introduced in the course and provided for students. In the “Demonstration” section, students are led through the process of circuit setup and basic data acquisition stages. Once data is received by the host VI, students are asked to “Apply” their data processing skills to perform hands on calibration of each sensor and perform an averaging operation to filter high frequency noise. In the final “Extend” section, students are challenged to recalibrate their sensors and attempt to design a heart rate measurement using small variations in force applied to each sensor. Each sensor system is compared quantitatively using sensitivity, drift, and resolution as key figures of merit. Students report on the success or failure of the measurement and identify key steps for improvement.

Virtual Adaptation

As a result of the COVID-19 pandemic, the laboratory activities were rapidly adapted for virtual, remote, synchronous delivery. To achieve a development sequence that mirrored the intended laboratory process, the activities were separated in to two parts: initial demonstration, VI demonstration, and group-based application and extension activities. The laboratory sessions were delivered synchronously using the Zoom web conferencing platform. The instructor would use multiple webcams to discuss the transducer connections, the physical components used, and their purpose in the sensor system. Datasets were collected either during this demonstration period or prior to the laboratory session for distribution to students for analysis. A key portion of each demonstration session was a component of the VI that reads raw data from the distributed .csv file as if students were actively collecting data. This was to simulate the collection process and allow students a surrogate data collection and analysis experience in a virtual setting. The next demonstration portion was presented in a “follow along” style, with students asked to repeat steps taken by the instructor and confirm expected functionality. Students accessed LabVIEW software either through student licenses and local installations available through Cal Poly, or via a virtualized instance of LabVIEW streamed through Amazon Webservices App Server supported by Cal Poly. Once students confirmed the core functionality expected from the “Demonstration” portion of the lab, they were grouped in breakout rooms with four to five members to complete the “Apply” portion and as much of the “Extend” portion as possible during the time allotted for the synchronous lab. Instructor and a teaching assistant actively cycled through breakout rooms to answer questions and troubleshoot individual student VIs.

Impact of Activities and Adaptation

The selection of activities and sensor systems, as well as the use of LabVIEW, was identified as a key strength of the lab. Survey data collected as part of this intervention was limited by a very low response rate (n=5). What data was received indicated that the adaptations that were required as a result of the shift to virtual synchronous instruction were well received (Figure 1). Students indicated their desire to have had the real, hands-on experience of working with the transducers and sensors, but they felt that the adaptation provided a useful experience.

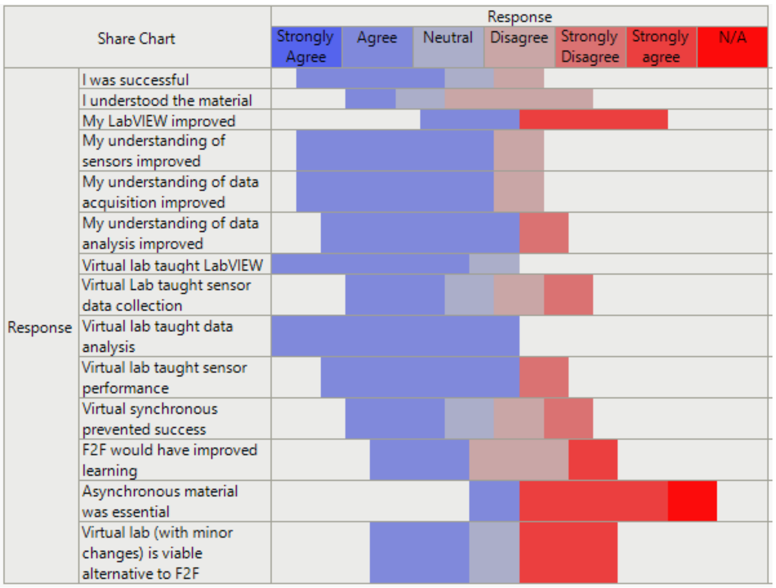

Figure 1: Survey responses (n=5) where students were asked to rate their response to various statements about the lab. Responses on a Likert scale went from "Strongly Disagree" (SD) to "Strongly Agree" (SA)

Conclusion

We have developed a sequence of laboratory activities that address measurement challenges from a variety of energy sources (e.g. mechanical, thermal, electrical) within the biomedical engineering context. The course material goes beyond simply understanding the "how" of a particular measurement and challenges students to connect the physics of a transduction mechanism and the physiological process being measured, the intermediate amplification, filtering, and conversion stages of the data acquisition process, and the calibration and validation operations conducted on the data to the quantitative figures of merit that define the performance of a particular measurement system. Each activity builds on the next, challenging students to build a more complete sensor system for each transduction mechanism. The laboratory activities were adapted to a virtual setting by demonstrating the data collection process on the instructors end and simulating the data collection process on the students end. This method involved a minimum of overhead and proved effective given the compressed timetable over which it was implemented.

Future work will take advantage of the LabVIEW ELVIS III system's ability to form a network connection and communicate data, allowing students to experience direct data collection over a network connection.