Extended Abstract-Preliminary Assessment of an Intercollegiate Freshman Engineering Project on Contrasting Automatic Blood Pressure Measurement Methods

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Abstract - **We describe a new intercollegiate freshman mini-project course, discuss its objectives, identify outcomes, report on results of an initial assessment, and discuss our plans to conduct additional assessment. The mini-project, titled "Automatic Blood Pressure Measurement," employs two novel educational approaches. First, we introduce freshman students to engineering design/development by contrasting several blood pressure measurement approaches implemented on different digital processors. This fosters innovation in design by providing students with a direct experience in investigating tradeoffs between different approaches. Second, we use an intercollegiate team of faculty, from Biology, Nursing, Chemical Engineering, and Electrical and Computer Engineering departments, to present this course. This provides an opportunity for freshman students to gain insights directly from the experts in their respective fields and inherently demonstrates the multidisciplinary nature of engineering.**

Index Terms – biomedical engineering, blood pressure measurement, intercollegiate, interdisciplinary

INTRODUCTION

The College of Engineering at Villanova University offers five undergraduate programs. These programs begin with a common freshman core sequence. A new freshman engineering core course sequence was initiated in Fall 2009 [1]. This six-credit two-semester sequence is divided into four half semester blocks. The first half semester block is the Core Course, consisting of lectures and micro (one-class) projects; the middle two half semester blocks are seven-week long multidisciplinary mini-projects; and the last half semester block consists of program-specific mini-courses. In a given academic year, about six different mini-projects are offered in each of the two mini-project time slots. A student experiences two of these projects of his/her choice.

In this paper we describe one of these mini-projects, on contrasting different automatic blood pressure measurement approaches, which we introduced in Fall 2011. We selected three noninvasive approaches which are all based on using an arm pressure cuff. These approaches are the automatic stethoscope (a.k.a. sphygmomanometry) approach, the oscillometric approach, and the finger-pulse approach.

In the sections to follow, we first describe the three automatic blood pressure measurement approaches. Then, in the context of the course structure, we present the objectives of this mini-project; identify outcomes associated with the objectives; and report on results of an initial assessment of the outcomes. Finally, we discuss our plans to conduct additional assessment of this mini-project course.

AUTOMATIC BLOOD PRESSURE APPROACHES

We selected three noninvasive approaches which are based on using an arm pressure cuff and we decided to use an air pressure pump controlled by a commercial device so the students focus in labs would be on sensors, interfacing electronics and digital processors rather than motor control and measurement timing issues. The cuff is pumped up beyond systolic pressure. Air is then slowly released as a pressure signal is acquired using a pressure sensor connected to the cuff through an air tube. What differentiates the three approaches the students consider is how the information is derived about when to read the pressure for the systolic and diastolic values. This information is based on using different pulse signals.

The automatic stethoscope approach [2,3] is based on the manual approach for which a health care professional releases the pressure from the arm cuff while listening for Korotkoff sounds with a stethoscope placed above the brachial artery. The first sound, caused by blood pressure first overcoming the cuff pressure, indicates when to read for systolic pressure. The last sound heard indicates when to read for diastolic pressure. In this approach, students process the audio from a digital stethoscope. The oscillometric approach [2-5] is commonly employed in commercial devices. When to read the pressure signal can be derived from oscillometric pulses which, in a manual measurement, can be seen as small deflections riding on top of the falling pressure gauge needle. The cuff pressure output of a pressure sensor signal is high-pass filtered [5] to extract the oscillometric signal. The finger-pulse approach uses the characteristics of the finger pulse. When the pressure in the cuff is above systolic level, no blood flows into the lower arm and no pulse exists in the finger. As the cuff pressure is lowered below systolic level, a small volume of blood is pumped into the lower arm, and a faint pulse can be observed in a finger. The first pulse detected by a finger-pulse sensor indicates when to read systolic pressure. Diastolic pressure is measured at the time when the pulse amplitudes level out.

MINI-PROJECT OBJECTIVES

The objectives of this mini-project are to: 1) exemplify the engineering design/development process; 2) expose students to multidisciplinary aspects of engineering; 3) motivate students to continue their pursuit of an engineering profession; and 4) build an automatic blood pressure measurement device while experiencing most aspects of the engineering design/development process.

I. Objective 1: Engineering Design/Development Process

Table I lists the class activities including lectures and labs. In Class 1 of this project, we emphasize that the project is structured to parallel an engineering design/development process, but that it is not an actual design/development process. We point out that certain steps and issues representative of a realistic process are missing, and that while each step taken exemplifies the design/development process, it is substantially simplified. Progressing through the project, it quickly becomes apparent that in a real process each step would require significantly more focus. That is, the engineering design/development process is more challenging than what might be suggested in a movie, TV show or advertisement.

The design/development steps that we focus on in this project are: 1) gathering multidisciplinary expertise (Classes 1-4); 2) preliminary investigation (Classes 4-6); 3) sensor & analog circuit development (Class 7-9); and 4) digital processor development (Class 10-14). We emphasize that these steps are not necessarily completed sequentially, i.e., the team may decide to revisit step 1 while in step 2. We also stress that this project does not present the complete design/development picture. In Class 10 we discuss the other considerations which we had not emphasized, including resources and costs, design specifications, embedding processors, and design for manufacturing.

II. Objective 2: Multidisciplinary Aspects of Engineering

We use lecture time to introduce each required project “expertise”. The project instructors (Khuon & Buckley) provide expertise in sensors, signal processing, circuits and digital processors. Additionally, faculty from chemical engineering, biology and nursing provide their related expertise. Lectures are very interactive, consisting of Powerpoint, Web-based exploration, constant instructor/student exchange, and team problem solving. These lectures exemplify the gathering of the multidisciplinary expertise required for a successful development.

III. Objective 3: Pursuit of Engineering Profession

To motivate students to get excited about engineering, we make extensive use of cooperative and active learning. Students working in teams in lab and lectures incorporate active learning techniques. We chose an interesting and relevant application (health care, automatic blood pressure measurement) as a vehicle for exemplifying the engineering design/development process. We use a "scenario" video, and related discussions of engineering in every-day life, to direct students to the realizations that: 1) engineering is all around us; and 2) that our exposure to engineering in every-day life is overly simplified. We use several scenes from action movies as examples of over-simplified portrayal of the design/development process given resources of opportunity, as well as examples from advertising which under-emphasize or even misrepresent engineering. The "scenario" video is a project requirement. Each student design team must submit a short video which, for example, portrays a typical action hero device development scene, except that when it is time to develop the device, a realistic engineering design/development process is emphasized. We evaluate these videos using the following criteria. The video should be fun, relate to automatic blood pressure measurement, and illustrate the engineering design/development process.

IV. Objective 4: Build & Experience Process

Labs 1 through 4, as shown in Table I, are the focus of this project course. The lectures introduce and support these labs. For each lab, students are required to submit a Report Form which requires an Instructor/TA signature for each significant step. This serves to require students to discuss/question their understanding and to interact with an instructor/TA. In Lab 4, students complete the project’s development steps as they acquire the blood pressure signals using the sensors, analog electronics, and digital processors and real-time process the blood pressure measurement.

OUTCOMES AND INITIAL ASSESSMENT RESULTS

For each of the objectives stated earlier, we have defined outcomes. What follow are results of a preliminary assessment of these outcomes.

TABLE I
PROJECT SCHEDULE OF LECTURE AND LAB ACTIVITIES

Class #	Type	Topic
1	Lecture	Introduction: motivation, blood pressure measurement approaches (Buckley & Khuon, Electrical &Comp Eng)
2	Lecture	Fluid dynamics & blood pressure (Kelly, Chemical Eng)
3	Lecture	Cardiovascular physiology (Stephens, Biology)
4	Lecture /Lab 1	Health care & blood pressure; Manual blood pressure measurement (Capriotti, Nursing)
5-6	Lab 2	Blood pressure signal evaluation & signal processing in Matlab (provided signals)
7	Lecture	Sensors & analog interface electronics (Khuon, ECE)
8-9	Lab 3	Sensors & analog electronics: build filter to derive oscillometric signal from cuff pressure signal
10	Lecture	Digital processors & development systems (Buckley, ECE)
11-12	Lab 4a	Acquiring blood pressure signals onto desktop, evaluate and process in Matlab (as in Lab 2)
13-14	Lab 4b	Acquiring blood pressure signals into digital processor, process in real-time for blood pressure measurement

- **Objective 1 Outcome**: Students can successfully associate different topics introduced with different steps in the engineering design/development process.

In a quiz taken at the end of the project in Spring 2012, students were asked to match the following engineering design process phases: a) Understand problem; b) Preliminary investigation; c) Sensor/analog electronics development; d) Processor development with the following lab objectives: i) To acquire a basic ability to use the processor development system, utilize analog interface hardware and processor development system to acquire and plot pressure and pulse signals, and develop a real-time digital signal processing based blood pressure measurement device; ii) To perform a manual blood pressure measurement and understand the safety issue as well as issues in signal quality for an automatic measurement system; iii) To become familiar with Matlab and to explore the process of evaluating signals which are candidates to be used in a blood pressure measurement device and consider how these signals might be processed so as to estimate blood pressure; and iv) To give a feel for electronic circuit construction, characterization, & verification, which, in addition to design and simulation, are necessary aspects of electronic engineering. Students answered this question with 76.5% accuracy, indicating that in general they understood how the project labs paralleled the engineering design/development process.

- **Objective 2 Outcome**: Students can successfully answer questions concerning the reliance of different disciplines to accomplish an automatic blood pressure measurement device design/development.

In a survey taken at the end of the project in Spring 2012, students were instructed to describe the activities of the fields in relation to the design of the automatic blood pressure measurement device: a) Electrical and computer engineering; b) Human physiology/biology; and c) Medical/health care. In assessing their responses, we defined the following numerical rubric scale:

1. Limited (score 1): the student was unable to describe most of the major activities;
2. Satisfactory (2): the student was able to describe several but not all of the major activities;
3. Mastered (3): the student accurately described all of the major activities.

Two instructors performed the assessment. On a 1-to-3 scale, the mean was 2.23 and the standard deviation was 0.62. This result is good but we plan to improve.

- **Objective 3 Outcome**: Students found the project intellectually stimulating.

At the end of our first offering of this project, in December 2011, each student filled out a standard Villanova University Course and Teacher Survery (CATS). This survey is intended to provide student feedback on the quality of the course and instruction. In this CATS results, response to the statement "I found the course intellectually stimulating" was very positive. 61% of the students strongly agreed with this statement, and 32% agreed.

- **Objective 4 Outcome**: Teams successfully implement real-time automatic blood pressure measurement for their measurement approach and digital processor.

Lab 4 culminates with each team demonstrating a functioning blood pressure measurement device to an instructor. Although an accurate reading is not required, to be judged successful, we expect a team to be able to show good signal acquisition technique, good acquired signals, an understanding of the underlying signal processing, and a reasonable result. Of the 11 design teams for the Spring 2012 offering, all were successful.

FUTURE ASSESSMENT PLANS

We began formally assessing our course in the Spring 2012 after successfully offering it for the first time in Fall 2011. Due to the structure of the freshman core course sequence, students in the spring semester had already completed one of the other multi-disciplinary mini-project and likely were exposed to some aspects in our objectives. We plan to assess this Fall 2012 with the incoming freshman students to compare and contrast a first versus secondary exposure to the engineering design/development process and the multidisciplinary aspects of engineering. Additionally, our course is unique among the other Villanova University College of Engineering freshman mini-projects in that the faculty instructors consist of faculty outside the engineering college. We plan to assess how an exposure to non-engineering faculty impacts the students' understanding of the multidisciplinary aspects of engineering and their desire to pursue the engineering profession. We also plan to collect data (students declaration of major in their sophomore year) to assess the potential effectiveness of our course in retaining students in the field of engineering as well as specific areas such as electrical, computer, chemical, and biomedical engineering.

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REFERENCES

[1] Caverly, R., Fulmar, H., Santhanam, S., Singh, P., O'Brien, J. et al., "Project-based freshman engineering experience: the core course," *ASEE Annual Meeting*, 2010.

[2] Nitzan, M., "Automatic Noninvasive Measurement of Arterial Blood Pressure," *IEEE Instrumentation & Measurement Magazine*, February 2011, pp. 32-37.

[3] Neuman, M., "Measurement of Blood Pressure," *IEEE Pulse Magazine*, Mar.-Apr. 2011, pp. 39-44.

[4] Drzewiecki, G., Hood, R. and Apple, H., "Theory of the Oscillometric Maximum and the Systolic and Diastolic Ratios," *Annals of Biomedical Engineering*, Vol. 22, 1994, pp. 88-96.

[5] Chua, C.S. and Hin, S.M., "Digital Blood Pressure Meter," *Freescale Semiconductor Application Note*, AN1571, Rev 1, 05/2005.