Development of Course Modules for Multidisciplinary STEM Education

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Abstract **- Traditional STEM education models in electrical engineering and computer science rely on structured classes, laboratories, and textbooks to transfer key concepts. Even though this process meets most of the ABET objectives, it does not respond well to current workforce needs that require widely accessible programs that will provide a large pool of graduates with STEM backgrounds, analytical and programming skills, critical thinking, and leadership abilities. In this work in progress paper, we describe our efforts to motivate students to pursue studies in STEM areas. We accomplish this by creating and disseminating modules that demonstrate how math and engineering theory enable modern applications such as those embedded in wireless devices.**

Keywords—Digital Signal Processing, STEM Education, mobile learning, online learning

I. INTRODUCTION

STEM courses in electrical engineering and computer science typically use class, laboratory, and textbook materials to cover theory and practice in their plans of study. Although these methods are generally accepted they do not provide the required skillsets, critical thinking capacity, and leadership abilities to prepare a modern workforce. Moreover the lack of sufficient connections between STEM theory and modern applications in courses affect recruitment and retention nearly at all levels of education.

The purpose of this paper is to describe work in progress towards motivating students to pursue further studies in STEM related areas at all levels of education. This collaborative program includes activities, development and workshops across disciplines. The hypothesis is that if strong connections are made between STEM theory and applications we will observe increased interest in pursuing STEM related studies.
Our plan is to develop, disseminate and assess modules that demonstrate how engineering and math theory are key to creating successful cutting edge high tech apps and products such as those embedded in smart phones. The modules contain Internet streamed lectures and various forms of software and lab content that enable students to understand how STEM theory is embedded in modern applications. Another objective of the program is skill building across disciplines and universities which will be realized by programming and testing algorithms at least two computer languages.

As an example, applications of Fourier spectra to wireless sensors, as utilized in radar and health monitoring, can be used to generate STEM computing modules for Engineering and non-Engineering undergraduate classes, and will provide STEM application experiences to students.

Modules will cover various aspects of engineering, including: a) software implementation of DSP algorithms on mobile platforms; b) examination of algorithmic computational complexity and its impact on mobile apps; and c) software development skill building for multiple platforms including Java, MATLAB, and Android. The program has a strong multidisciplinary component which is based on the fact that signal and information processing is embedded in many science and engineering fields including arts, media and engineering programs. Multidisciplinary materials will be developed and modules will be immersed in courses in Arts and Media, Biomedical Informatics, and Geology classes of partner universities. Modules are being tested and currently assessed in our DSP and signals and systems classes and we are beginning to compile preliminary evaluations. Summer workshops that include skill building sessions and assessment activities are part of the program. A workshop was held in June 2016 where one of the training modules was disseminated to a group of students and practitioners.

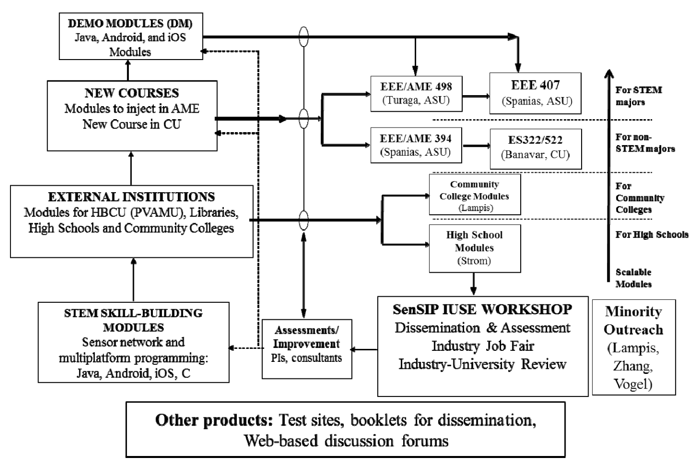

Figure 1. Module Creation, Deployment and Assessment.

Lab exercises will promote algorithm understanding and provide programming skills for high-tech workforce [48] creation. Implementation and dissemination on mobile platforms can help create a community of diverse users through content that can be used in universities, community colleges and high schools. These modules will be immersed in several courses in engineering and other fields such as arts and media, earth systems and geosciences, and health monitoring (Figure 1).

The authors at ASU are being supported in part by the NSF award 1525716 and the SenSIP center. M.K. Banavar at Clarkson University is supported in part by the NSF DUE award 1525224.

The program also includes outreach and recruitment efforts. Previous outreach activities have included demonstrations at CDS High School and Phoenix College. Planned outreach activities and their assessments will be presented at the conference. These include a workshop with all collaborators planned for May 2016 at Arizona State University, and high school and community college workshops planned in Spring 2016. Collaboration and disseminations also include activities with University of New Mexico, University of Cyprus (UCy), Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM), Imperial College London, and John Hopkins University.

Hypothesis and Specific Objectives

Several students at the early stages in science and engineering and in high schools have not often expressed a positive attitude towards STEM theory and applications. This in turn creates problems in recruitment and retention of students and also in creating a STEM workforce. The hypothesis is that these problems are often due to lack of knowledge on how STEM theory enables innovative high tech products such as smart phones, music players, etc. This project intends to solve this problem by creating modules to immerse in courses and workshops with the intent to create a more positive attitude towards STEM. Specific objectives include:

a. exposing students early to modern algorithms to enable them to understand how basic STEM topics relate to high tech products, e.g. Fourier and MP3, iPhone and spectra;
b. developing a national forum with STEM algorithm modules with the focus on sensor networks;
c. Engaging industry in the STEM workshops and reviews;
d. Providing algorithm design and computational skills;
e. Disseminating odules, methods, products, and activities;
f. Using our program strategies for recruitmentin STEM areas.

II. Prior Education and research Experiences

We have previously established research and education programs that included several education tools and content related signal processing, and sensor network applications. In particular, we have developed materials from (a) an NSF Tues Phase 3 program, (b) curriculum entries from an Arts and Media IGERT, and (c) industry projects and training relating to our industry Consortium (which is also an I/UCRC site).

A. Immersion of Tools and Results in Modules

Applications of Fourier spectra to wireless sensors, as utilized in radar and health monitoring, can be used to generate STEM computing modules for our Engineering and non-Engineering classes. We use sensor results [1,2] to develop computing modules for sensors; these modules are injected in undergraduate courses (EEE394/307 at ASU and EE322 at CU for non-STEM and EEE407 at ASU and EE401 at CU for STEM) and provide STEM application experiences to undergraduate and graduate students as shown in Figure 1. Computing and software aspects of the algorithms are emphasized. These modules cover various aspects of software engineering, including: a) software implementation on mobile platforms, b) implementation issues including computational complexity, and c) exposure to software for six different platforms, i.e., Java, MATLAB, LabVIEW, Android, Objective C, and Texas Instruments DSP assembly language.

B. Application Content and Industry Participation

The authors at ASU have extensive industry relations managed through a consortium agreement that also has a significant training component. Our Industry Consortium has six members, namely Raytheon Missile Systems, Intel Corporation, NXP, Sprint, ViaSOL Energy, Applied Core Technologies, and Interactive Flow Systems. All companies support graduate projects related to algorithms and software for digital signal processing, health monitoring, environmental applications, defense, security, and sensor networks.

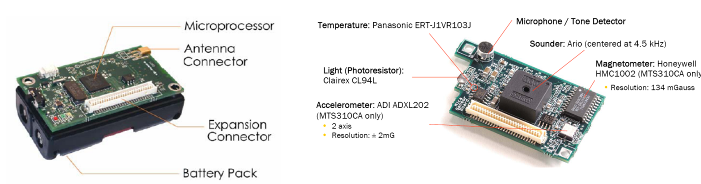

Figure 2. Sensor Motes (a) transceiver; (b) sensor board (printed by Crossbow/MOOG permission).

Some of the projects use the real-time Crossbow/Moog wireless sensor motes (Figure 2) and Freescale Xtrinsic sensor boards to program various detection algorithms associated with sound source, mobile phone, and sensor localization. We have used results and algorithms [3] from these programs to form education modules with computing content. We began to use these modules in undergraduate EE, AME and Global Health courses as shown in Figure 1.

The sensor motes use the TinyOS, operating system [4,5]. The TinyOS libraries and applications are written in nesC. The nesC is a dialect of the C language and is designed for component-based applications. The grammar of nesC is an extension of the ANSI C [5]. Extensions to newer Freescale (NXP) circuits will also be integrated.

A graphical user interface (GUI) has been established in our award winning J-DSP [3,6,9,12-14] to interface the Crossbow/MOOG sensor hardware with the PC. This universally accessible J-DSP GUI is a user-friendly software layer (Figure 3) that provides access to a hardware sensor network and enables remote sensing using the TCP/IP protocol; the Mote block in J-DSP allows users to control the motes and base station.

Demonstrations include using recorded sensor data for activity recognition, and other health monitoring applications [7,8]. Simple approaches use the Fourier series to study periodicity. More complex methods use machine learning and adaptive learning techniques.

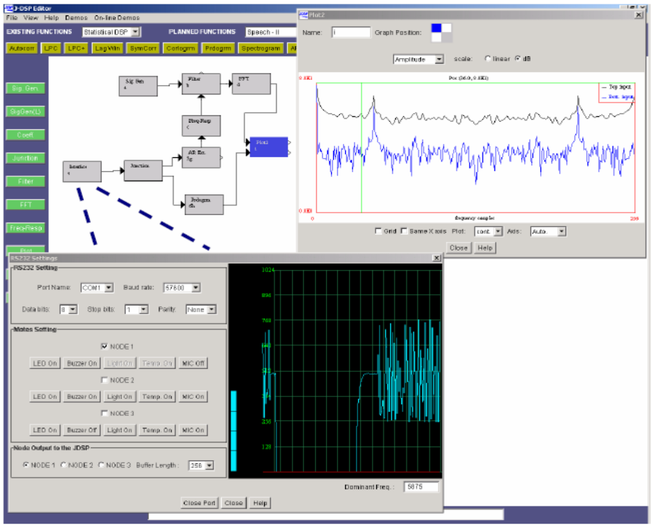

Figure 3. J-DSP interface to Sensor Motes used in education modules; Internet sensor simulations help create a community of sensor network software users.

The hardware sensor network with the motes and J-DSP is used:

- in the STEM education modules as shown in Figure 1;
- in providing programming experiences to students; and
- to realize remote sensing computing scenarios using the TCP/IP protocol.

C. *Software tools for collaborative sensor computing*

The J-DSP environment described in the previous section supports collaborative scheduling and simulations through a "blackboard" visual programming environment. The J-DSP feature that enables collaborative simulations is called *J-DSP Scripts* [9]. Students from different universities are able to integrate and run simulations concurrently. In this manner the students can form together a joint sensor network simulation, exchange ideas and results, design and test sensor systems.

III. Research Exposure and Skill Building

The current project includes several components such as sensor networks education, involving undergraduate students in research activities, and work with high schools and community colleges.

A. *Sensor networks across different platforms*

In this project, we provide diverse programming skills and provide educational experiences across different hardware and software platforms. Research and computing laboratory exercises are being developed with Android [10], iOS [11], MATLAB [12], HTML [9], Java, LabVIEW [13], Tiny OS NesC [3], and TI DSP assembly [14]. We have developed software interfaces of J-DSP with MATLAB [12], HTML [9], LabVIEW [13]; we also developed interfaces to the TI DSK board and the Crossbow/MOOG sensor motes [3,6]. Recent work also includes development of apps for Android tablets and mobile phones (AJDSP) [10], as well as apps for iOS devices such as the iPhone, the iPad, and the iPod Touch (iJDSP) [11]. These apps include modules for noise cancellation, accelerometer-based activity detection, and video-based heart rate monitoring using the photoplethysmogram (PPG) [7].

B. *Involving Undergraduate Students in Research*

Undergraduate students are engaged as part of our program. The students assist in module development, as well as in dissemination efforts. The undergraduate students participating in these activities learn mathematical and engineering concepts, design and management of projects, technical writing, and presentations. In our program, we worked with undergraduate students as part of prior research experiences for undergraduates (REU) and research experiences for veterans (REV). In these efforts, we developed Android apps for ranging and localization [8].

IV. Outreach, Dissemination, Assessments

In a previous collaborative program we worked with four universities, namely the University of Washington Bothell (UWB), Johns Hopkins University, and Prairie View A&M (PVAMU). The program resulted in several educational technology innovations with software development and online laboratory design. This multi-university relationship already has mirror sites, which we use to disseminate modules.

Collaborations have also been established with other disciplines beyond electrical and computer engineering environments. Multidisciplinary collaborations will build software for earth systems and geology [17,18]. Collaborations with the AME Program [15,16] at ASU will develop next generation experiential media systems via immersive audio and visual feedback. The EEE394 Signal Processing for digital culture course, which is part of SM3 (see Figure 1), is specifically designed to teach signal processing to students in non-STEM majors. The course was already offered and assessed twice.

A. *K-12 Outreach*

Creating positive attitudes and recruiting students in STEM areas starts with K-12 [22,23,25]. We planned and began K-12 outreach activities that bring together the School of ECEE at ASU with a high school Mathematics teacher to develop and design mobile content for introducing engineering technology to high school students. More specifically, we have designed and implemented sequence of modules that will establish connections between high school Mathematics to modern coding [21,24,30,35,37] technologies associated with smart phones, iPods, iPhones and other high-tech products [19]. In planning the assessment outreach and dissemination, we will examine results of previous studies [38-41] as well as our previous experiences with assessing J-DSP [6].

B. *Dissemination*

One of the main objectives of the K-12 portion of our program is to show how Mathematics concepts are at the core of the algorithms that enable mobile phones, digital cameras, YouTube, Skype, and other technologies. DSP Apps [7,19,45] developed for iPhone and Android platforms will be accompanied by modules that will be adapted for dissemination in high school Mathematics classes. We will also use established sites for dissemination such as Connexions [42,43] and also other best practices established in signals and systems education research [44,46,47]

C. Assessments

Evaluations [25-29] are planned for our STEM modules, dissemination and outreach. The hypothesis is that students in our target categories will be at the following positions after they complete the STEM modules.

Undergraduate STEM students will:

- Have an appreciation of the state-of-the-art and research frontier in the computing areas covered;
- Students can ask substantive questions after a presentation in an area covered in EEE/AME 498;
- Students will be able to perform appropriate software reviews in the field that they were exposed;
- Students appreciate research and are excited by the prospect of doing open ended work;
- Students are interested in attending graduate schools to perform thesis research.

Undergraduate non-STEM students will:

- Have an appreciation of the applications of STEM concepts in their areas;
- Students can ask substantive questions after a presentation in an area covered in EEE/ASB 498;
- Students are excited by the prospect of incorporating mathematics and engineering in their research.

K-12 engagement will:

- Encourage more students to enroll in STEM majors in college;
- Better prepare students for the college STEM curriculum;
- Encourage teachers in the K-12 system to participate in STEM activities to better help prepare high school students for college.

For every module and for the entire STEM project, we will devise a qualitative and quantitative assessment process. Assessments will be done through electronic web tools, pre- and post- quizzes, presentations, one-to-one interviews, and ordinary in-class testing.

Evaluation will be carried out in three stages with both formative and summative assessments [22,23]. The three stages of the evaluation process are as follows:

(i) Prior to implementation, objectives are defined, as well as procedures to achieve them, and their impact. Evaluation methods and tools will be matched with project objectives;

(ii) Formative assessments are performed periodically throughout the lifetime of the project. They will be used to evaluate the effects of current implementations and tune the project to regain targets, and improve the design;

(iii) Summative assessments at the completion of the project will be used to determine the degree to which goals were achieved, as well as assess the impact of the project. The data and qualitative experiences will be useful for planning future projects.

V. CONCLUSIONS

This paper describes our work n progress towards creating STEM education modules to motivate students to pursue studies in STEM areas and to develop software skill building content for immersion into several courses. Our plan is to link the content in these modules to high tech products, and show how engineering and math theory are key to their creation. The modules contain streaming video lectures, software and lab content, and mobile apps to enable students to understand how STEM theory is embedded in modern applications. Planned work includes collaborations in multidisciplinary areas such as earth sciences, and arts and media. At this point three modules have been developed, an outreach session to a high school was held and a workshop with industry participants was held. Assessment and dissemination is also a current activity that is documented and preliminary results will be presented at the conference.

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