Android-Based Mobile Sensory System Labware for Embedded System Education

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***Abstract*—To overcome shortcomings in existing embedded system education, this paper presents an ongoing work on developing a novel *Android-based Mobile Sensory System Labware* that is portable, affordable, and easily adoptable. The proposed labware can greatly facilitate authentic and creative learning of embedded systems and provide extensive hands-on experiences using mobile embedded platforms readily available today. Preliminary feedback from the participating students is positive and encouraging.**

Keywords— Android, Embedded System, Labware, Sensor

I. INTRODUCTION

In recent years, embedded systems are becoming increasingly important due to their wide applications in every aspect of our society. They represent a key technology in modern industry, such as consumer electronics, industrial automation, military/aerospace, automotive industry, and telecommunications [1-3]. Examples of such embedded computing systems include, but not limit to, PDAs, automobile components, home appliances, and the recently popularized smart mobile devices (e.g., Smartphones and Tablet). The rapid growth of embedded systems results in a shortage of professionals for embedded system development, and more and more higher education institutions have realized the importance for computer science and software engineering students to be exposed to the engineering disciplines in design and development of embedded systems [4,5].

A key component in embedded system education is laboratory, and many efforts have been made to strengthen the hands-on experience of embedded system development (e.g., [6-8]). However, existing laboratories rely on two prerequisites, i.e., significant investment in resources (e.g., embedded system labs) and high requirement for instructors (e.g., faculty whose expertise is in this area). These prerequisites make the dissemination of existing instruction models highly dependent on the resources that an institution can afford. In addition, once set up, these labs are difficult to be integrated into other courses in the computing curriculum, or even the same courses taught by different instructors. This is usually due to the different requirements from instructors and different courses. For universities and colleges that lack resources and build-ups in embedded systems, the existing instructional models are difficult to adopt. A new affordable and easily adoptable approach to embedded laboratory is desirable for these institutions to enhance their embedded system education.

Over the past decade, the technology and market for smart mobile devices and open platforms have grown substantially. In year 2011, the shipments of Apple-iOS-based and Google-Android-based smartphones and tablets alone were about 400 million units, compared to 350 million units of traditional netbooks, notebooks, and desktops in total [9]. Moreover, they are more than 600,000 apps available for iOS and Android devices [10], turning these devices into powerful general-purpose computing platforms. These smart mobile devices and open platforms have expanded the connectivity and functionality of mobile embedded systems to a new era. In addition, empowered by a variety of different types of sensors, these systems become more capable of learning, thinking, and understanding the surrounding world. We envision that the next generation of mobile devices will have more powerful sensing functionalities and can further impact our economy and society in a profound way. To respond to industry needs, the embedded system education needs to be adapted accordingly and incorporate cutting-edge embedded knowledge and mobile embedded systems into the instructional and laboratory teaching materials.

This paper presents our ongoing work on developing a novel *Android-based Mobile Sensory System Labware* for embedded system education in universities and colleges that have limited resources for teaching undergraduate embedded systems courses. The labware is portable, affordable, and easy-to-adopt. By utilizing both built-in and external sensors for Android-based mobile devices, we aim at developing an authentic and creative embedded system learning environment to facilitate students experiencing with augmented reality and to encourage students to "innovate" and develop their own embedded systems.

II. ANDROID-BASED MOBILE SENSORY SYSTEM LABWARE

The main features of the *Android-based Mobile Sensory System Labware* include:

(1) *Promote student authentic learning*. Android devices with sensors can provide students with extensive opportunities on hands-on learning of collecting, processing, and analyzing authentic data in real-world applications. From our preliminary course experience, most students felt that they were immersed in such authentic learning environment with sensors and Android devices.

(2) *Promote student creative learning*. Students are coached first in pre-lab activities and lab activities followed by add-on projects and open-ended problems so that they will learn to think about the problems and how to solve them based on what they have learned. Students are also encouraged to create new Android applications using different sensors in their project activities.

(3) *Provide portable and affordable labware for hands-on embedded education*. The developed labware is based on affordable Android smartphones and sensors. This would remove the barrier of setting up high cost embedded system labs for learning embedded systems. Most students have their own smartphones with built in sensors, and most external off-the-shelf sensors cost only a few dollars.

(4) *Create an easy-to-adopt model to support wide dissemination*. The labware to be developed are modular and have multiple learning levels. The modular design gives instructors the flexibility either to use the labware in its entirety or to adopt selected modules based on their specific needs. The proposed labware will be delivered as an integrated package and deployed on a Google site to provide a "ready-to-adopt" model. It will greatly save resources and time for broadening embedded system education to meet the emerging workforce and education needs in science, technology, and engineering.

The labware covers basic, advanced, and emerging embedded system learning topics with authentic smartphone-sensor-based hands-on labs and projects. The labware consist of following modules:

- Module 1: Getting started with Android application development.
  - Android cross-platform development with Eclipse and device deployment
  - Android Java app development
- Module 2: Hardware-software co-design of Android-based mobile sensory embedded systems.
  - Introduction to sensors and Android API
  - Introduction to Microcontroller (MCU)
  - Introduction to Interfaces to Android devices
- Module 3: Android measurement apps with built-in internal sensors.
  - Compass app development
  - Slope app development
  - Distance app development
  - Lightness app development
- Module 4: Android-based mobile sensory embedded systems with external sensors.
  - Sensing through Bluetooth wireless interface
  - Sensing through Wi-Fi wireless interface
  - Sensing through USB interface
- Module 5: Android-based mobile sensory embedded system for actuators control.
  - Smart mouse development
  - Smart garage key development

In our *Android-based Mobile Sensory System labware*, sensors are used to collect raw data from physical world. The Android apps then convert the raw data obtained from the sensors to useful digital data, so that the data can be analyzed and used for device control. There are in general two types of sensors used in the labware: internal sensors and external sensors. Internal sensors are the built-in sensors existed in most Android devices today that are capable of detecting motion characteristics (such as accelerometers, gravity sensors, gyroscopes and rotational vector sensors) and measuring environmental parameters such as magnetic force, ambient temperature, pressure, and illumination among others. External sensors include various sensors (e.g. vibration and dust) that are not built in the Android devices. Most Android smart mobile devices can easily access raw data from many different types of external sensors or their associated MCUs via USB, Bluetooth, and Wi-Fi connections to conduct further data analysis and actuator controls. Fig.1 shows an example of Android-MCU-Sensor that we provided to students in the preliminary evaluation.

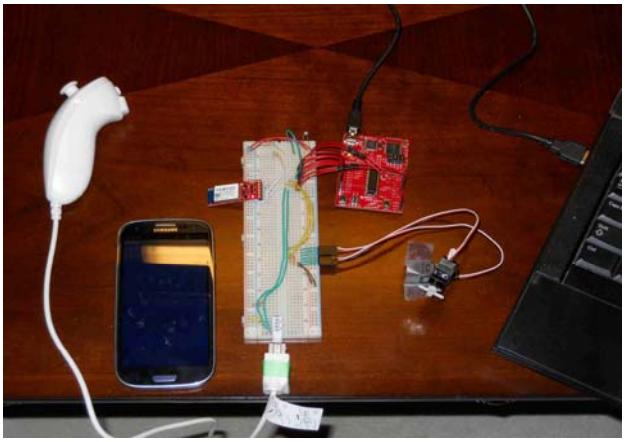
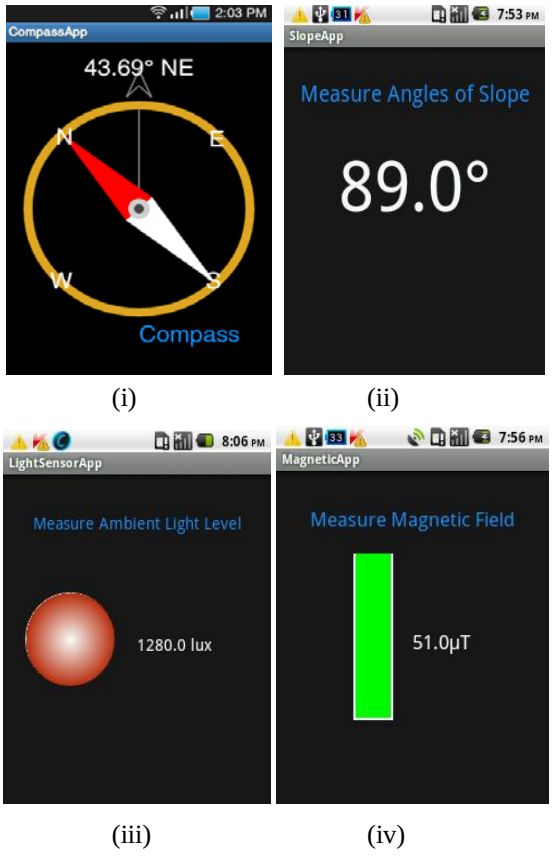


Fig. 1. Android external vibration sensory embedded system with Bluetooth

Each module in the labware contains: (1) pre-lab activities (concept introduction and lab preparation); (2) lab activities (working on internal sensors of smart devices and external sensors that are connected to smart devices via USB, Bluetooth, and Wi-Fi MCU modules); and (3) post-lab activities (student add-on labs and open-end projects).

Upon completion of this labware, students should have gained: (1) an understanding of the hardware-software co-design and implementation of embedded systems; (2) a basic mastery of embedded software programming skills over mobile embedded computing platforms; and (3) real world experiences of developing realistic sensing-based embedded systems and apps.

All learning materials and lab manual videos are freely accessible through a Google site. Because of this modular design, the labware can be easily integrated in undergraduate computing courses. Meanwhile, the hardware needed to teach these modules is minimized. One reusable low-cost lab kit that consists of Android devices, MCUs, and external sensors can be used for all lab modules. The Android devices can be from students themselves or can be obtained at a price about $50. The cost of MCUs and external sensors is about $30. All of above make the developed labware highly affordable and adoptable.



(i) (ii)

(iii) (iv)

Fig. 2. Screenshots of Four Developed Labs

Fig. 2 demonstrates some screenshots of the labs that have been developed by students in Module 3 of the labware, including (i) a compass app with built-in orientation sensor (geomagnetic field sensor and accelerometer); (ii) the angle of slope app using orientation sensor; (iii) the lightness measurement app using light sensor; and (iv) the magnetic field measurement app using geomagnetic field sensor.

III. Preliminary Evaluation

Several labs have been presented to students for preliminary evaluation. The feedback is positive and encouraging. Most students enjoy what they learned from the new labware. In particular, they are excited with the tremendous opportunity of hands-on working on the real-world embedded projects with the labware.

IV. Conclusion

This paper presents a novel *Android-based Mobile Sensory System Labware* for teaching undergraduate embedded systems courses in universities and colleges that have limited resources. The goal of this work is to improve student learning experience of embedded system to the degree that they are capable of filling tomorrow's mobile embedded system design workforce. In the future work, we plan to continue the development of the labware and to integrate it in multiple computing courses such as embedded systems, software engineering, system engineering, and capstone projects.

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