TEACHING CYBER-PHYSICAL SYSTEMS USING MIT APP INVENTOR 2

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Abstract

A Cyber-physical System (CPS) is defined as a system which combines computation and communication abilities along with monitoring and/or control entities in the physical environment. This definition shows how crucial the use of sensors and actuators are because they bridge between the cyber and the physical worlds. Currently, smartphones are equipped with many sensors. There is no doubt that smartphones are becoming, to many people, the primary communication device in their daily lives. Also, sensors allow smartphones to experience a revolution across a wide range of domains. Using sensors of smartphones in cyber-physical systems introduces mobile cyber-physical applications that are defined as computer systems which process and respond to data from the physical space and make decisions which influence it. It is anticipated that as sensors become smaller and cheaper, more markets will get introduced. MIT App Inventor is a blocks-based programming tool which simplifies building Android applications. It targets several audiences like educators, employees, volunteers, designers, product managers, researchers, and entrepreneurs. It deals with many types of sensors which makes it a great educational tool to teach cyber-physical systems for undergraduate and graduate students. Furthermore, this teaching methodology will enhance the students' skills in terms of dealing with this enormously growing market of smartphones and the world of applications. This paper presents several scenarios and examples of using MIT App Inventor 2 in a class setting to deal with AccelerometerSensor, Clock, Microphone, LocationSensor, and OrientationSensor.

Keywords: Cyber-physical Systems, Smartphones, Sensors, Android, MIT App Inventor 2, Teaching, internet of things, internet of everything.

1. INTRODUCTION

An inclusive definition of a Cyber-physical System (CPS) describes it as a system which combines computation and communication abilities along with monitoring and/or control entities in the physical environment (Guturu & Bhargava, April 2011). This definition shows how crucial the use of sensors and actuators are because they bridge between the cyber and the physical worlds (Khan, Xiang, Aalsalem, & Arshad, 2013). Table 1 compares and shows many smartphones and how many sensors they include. It is clear from the table that many recent smartphones from different manufacturers are equipped with many sensors.

Table 1. Comparison between different smartphones (Mechitov, 2014).

	Nexus One	Nexus S	iPhone4	Samsung Galaxy S	HTC Incredible	Galaxy Tab/ iPad2
Accelerometer	O	O	O	O	O	O
Magnetometer	O	O	O	O	O	O
Gyroscope		O	O	O		O
Light	O	O	O	O	O	O
Proximity	O	O	O	O	O	O
Camera	O	O	O	O	O	O
Voice	O	O	O	O	O	O
GPS	O	O	O	O	O	O

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There is no doubt that smartphones are becoming, to many people, the primary communication device in their daily lives. Sensors allow smartphones to experience a revolution across a wide range of domains as shown in figure 1 (Khan, Xiang, Aalsalem, & Arshad, 2013).

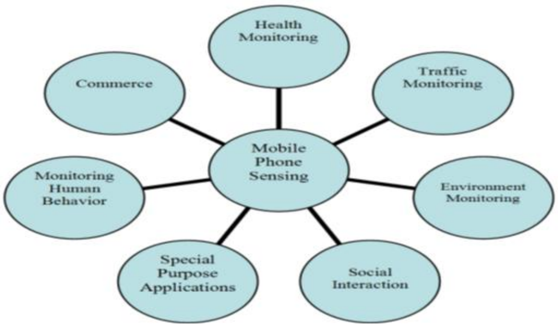

Fig. 1. The use of smartphone sensors in many areas (Khan, Xiang, Aalsalem, & Arshad, 2013).

Using sensors of smartphones in cyber-physical systems introduces mobile cyber-physical applications. A cyber-physical application is defined as a computer system which processes and responds to data from the physical space and makes decisions which influence it (Jules, et al., 2010). It is anticipated that as sensors become smaller and cheaper, more markets will get introduced. This anticipation will change the world (Maclay, 2014).

The platform of Android supports three wide-ranging types of sensors: Motion, Environmental, and Position sensors. Motion sensors usually determine acceleration and rotational forces alongside three axes. Furthermore, this type contains accelerometers, gravity sensors, gyroscopes, and rotational vector sensors. Environmental sensors, on the other hand, determine several environmental factors, like air temperature and pressure, illumination, and humidity. Also, this class contains barometers, photometers, and thermometers. Last but not least, position sensors determine the physical location of a device. This type contains orientation sensors and magnetometers.

Sensors in any Android device could be accessed by using the Android sensor framework. This framework offers many classes and interfaces which facilitate multiple tasks. Determining the availability and capability of sensors on a device is an example of some information that could be acquired using the platform. The Android sensor framework classifies sensors into two categories: hardware-based and software-based. Table 2 lists all supported sensors whether hardware or software-based (Google).

Table 2. Sensor types in Android platform (Google).

Sensor	Type	Common Uses
TYPE_ACCELEROMETER	HW	Motion detection (shake, tilt, etc.).
TYPE_AMBIENT_TEMPERATURE	HW	Monitoring air temperatures.
TYPE_GRAVITY	SW or HW	Motion detection (shake, tilt, etc.).
TYPE_GYROSCOPE	HW	Rotation detection (spin, turn, etc.).
TYPE_LIGHT	HW	Controlling screen brightness.
TYPE_LINEAR_ACCELERATION	SW or HW	Monitoring acceleration along a single axis.
TYPE_MAGNETIC_FIELD	HW	Creating a compass.
TYPE_ORIENTATION	SW	Determining device position.
TYPE_PRESSURE	HW	Monitoring air pressure changes.
TYPE_PROXIMITY	HW	Phone position during a call.
TYPE_RELATIVE_HUMIDITY	HW	Monitoring dewpoint, absolute, and relative humidity.
TYPE_ROTATION_VECTOR	SW or HW	Motion detection and rotation detection.
TYPE_TEMPERATURE	HW	Monitoring temperatures.

MIT App Inventor is a blocks-based programming tool which simplifies building Android applications. It was primarily established by Professor Hal Abelson along with a team from Google Education. It is maintained now by staff at The Center for Mobile Learning at MIT. It targets several audiences like educators, employees, volunteers, designers, product managers, researchers, and entrepreneurs (MIT App Inventor). It deals with the following types of sensors: AccelerometerSensor, BarcodeScanner, Clock, Camera, LocationSensor, NearField, and OrientationSensor (MIT App Inventor).

As far as the authors know, there is no paper published in the literature that combines both MIT app inventor 2 and CPS in a classroom environment, so it is novel to address this topic and propose this idea to the research community.

2. RELATED WORK

Many papers have been published that use sensors of smartphones in several areas. One of the most common areas was about indoor navigation like (Piras, DIATI - Dept. of Environ., Lingua, Dabove, & Aicardi, 2014) (Hardegger, et al., 2013). Other areas include: medical uses (Agu, et al., 2013) (Varadan, et al., 2011), traffic monitoring (Work & Bayen, 2008) (Ghose, et al., 2012), activity recognition (Shoaib, Scholten, & Havinga, 2013) (Anjum & Ilyas, 2013) (Lau & David, 2010), pH measurements of environmental water (Hossain, et al., 2014), environment sensing (Aram, Troiano, & Pasero, 2012), aggregation (Baranasuriya, Gilbert, Newport, & Rao, 2014), human smartphone interaction (Alepis, Virvou, & Drakoulis, 2014), augmented reality (Jung, Choi, & Hong, 2014), security (Lei, Wang, Zhou, Zha, & Zhang, 2013) and many more.

AppInventor.org is a website that teaches building android applications using MIT App Inventor. It provides a book and many tutorials that ease building complex apps. The website's materials have been modified and gathered from tutorials that have been created by Google and MIT. There are many applications that use many sensors (Wolber). These applications will definitely help in the educational process. MIT App Inventor has been used in education for many fields like teaching programming events (Turbak, Sherman, Martin, Wolber, & Pokress, 2014) and computer science fundamentals (Gray, Abelson, Wolber, & Friend, 2012).

3. METHEDOLOGY AND RESULTES

The Android application created in this work is published in the first author's website (http://www.uqu.edu.sa/gfbati). This application has been created using MIT App Inventor 2. The designer and blocks editor of MIT App Inventor 2 run entirely in the browser. Live testing refers to the idea of building the app while seeing it live in a device as it is developed. There are three options for setting up live testing. MIT highly recommends the option of using an android device equipped with a wireless internet connection and App Inventor Companion app to activate live testing (MIT App Inventor). Also, this app has been tested in a Samsung Galaxy S III cellphone (GT-I9300) that runs Android 4.3.

3.1. MICROPHONE

This part of the app teaches the use of the phone's microphone as a sensor. The following components are needed in the design of this part: SpeechRecognizer, Buttons, and Label. Figure 2 shows the components and the blocks that are used in this part of the app.

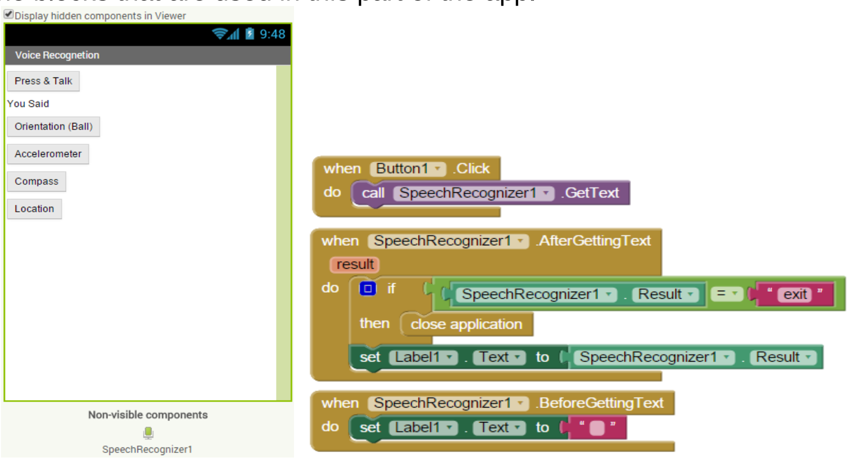

Fig. 2. The components and blocks of part 3.1.

When the first button is pressed, the speech recognizer component listens to the user's speech and presents it as a written text using Android's speech recognition feature. If the user says "exit", the app will be closed. The remaining buttons allows the user to choose another screen in the app (MIT App Inventor) (MIT App Inventor).

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3.2. OREINTATION

An orientation sensor component is used to measure the phone's spatial orientation. It measures three values. First, roll which equals 0 degree when the phone is level. It increases to 90 degrees if the phone is tilted up onto its left side or decreases to −90 if it is tilted up onto its right side. Second, pitch which equals 0 degree when the phone is level. It increases to 90 degrees when the phone is tilted while its top is pointing down and decreases to 0 degree as it is turned over, and vice versa. Third, azimuth which is equivalent to 0 degree the minute the top of the device is directing north, 90 degrees when it is facing east, 180 degrees while it is directing south, etc. (MIT App Inventor).

This part of the app teaches the use of orientation sensor to move a ball that appears on the screen of the phone when it is tilted by the user depending on the sensor's angle. The following components are needed: Canvas, Ball, OrientationSensor, and Clock. Figure 3 shows the components and the blocks that are used in this part of the app.

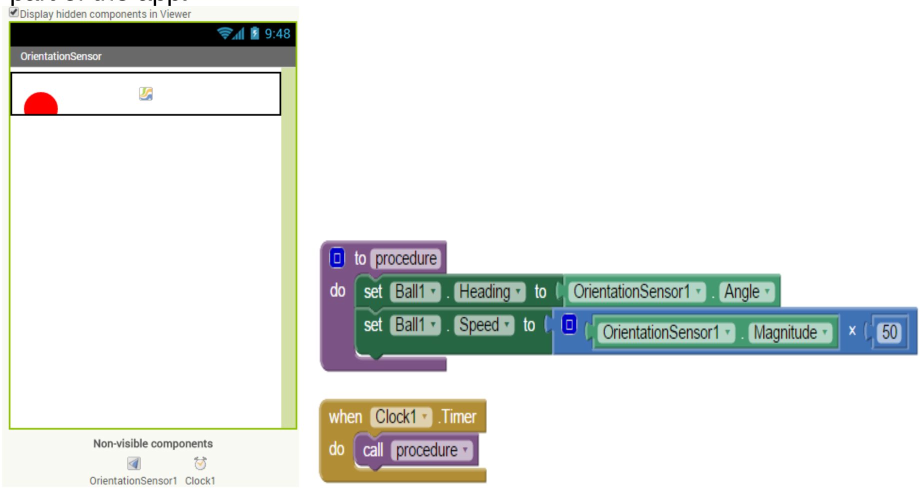

Fig. 3. The components and blocks of part 3.2.

The procedure moves the ball in the direction that the phone is tilted. The OrientationSensor angle is used to determine the ball's direction to move based on what angle the phone is tilted. Also, the OrientationSensor magnitude is used to calculate the ball's speed of movement based on how much tilt is put on the phone. Whenever the clock timer fires, the procedure will be called (MIT App Inventor).

A famous use of orientation sensors is in compasses. The following part of the app explains how to do so. The following components are needed: Canvas, ImageSprite, OrientationSensor, and Label. Figure 4 shows the components and the blocks that are used in this part of the app.

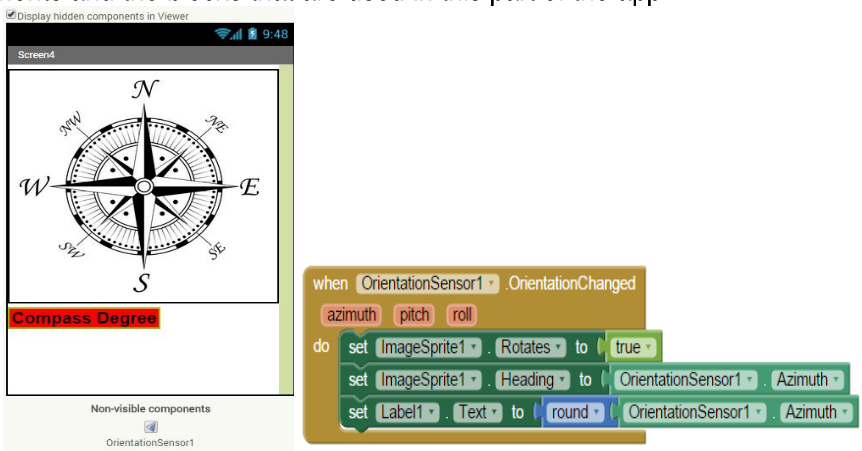

Fig. 4. The components and blocks of the compass.

The ImageSprite (compass picture) rotates when the OrientationSensor azimuth value changes which determines the direction of the compass. The degree of the compass is presented in the label after it is rounded (NOVALERTdotcom's channel, 2012).

3.3. ACCELEROMETER

An accelerometer sensor component is used to detect shaking of the phone and determines acceleration approximately in three dimensions: xAccel, yAccel, and zAccel (MIT App Inventor). This part of the app shows the use of an accelerometer sensor to detect when the phone is shaken to send an email as a response to the shake. Next components are needed in this part: AccelerometerSensor, ActivityStarter, Labels, and Buttons. Figure 5 shows the components and the blocks that are required here.

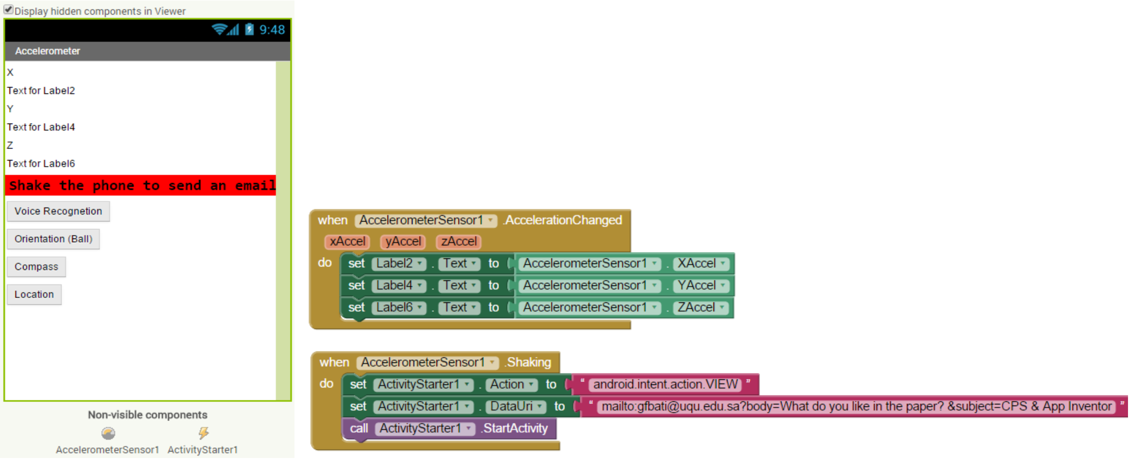

Fig. 5. The components and blocks of part 3.3.

The three values of the accelerometer are determined and presented in the labels. If the device is shaken, an activity will be started. Although ActivityStarter is designed for advanced developers, it is a crucial tool that expands the capabilities of MIT App Inventor 2 by starting other apps (MIT App Inventor). The mail client in the phone will be initiated to email to "gfbati@uqu.edu.sa" the following: "What do you like in the paper?". Also, the email will be titled "CPS & App Inventor" as presented in figure 5. The remaining buttons facilitates moving between different screens of the app.

3.4. LOCATION

A location sensor component provides the following location information: longitude, latitude, altitude, and address. The previous information needs either wireless networks or GPS satellites to be generated (MIT App Inventor). This part of the app teaches the use of a location sensor to detect the user's address and visualize it. The following components are desired in this part: LocationSensor, ActivityStarter, Labels, List, and Buttons. Figure 6 displays the components and the blocks that are used here (Wolber).

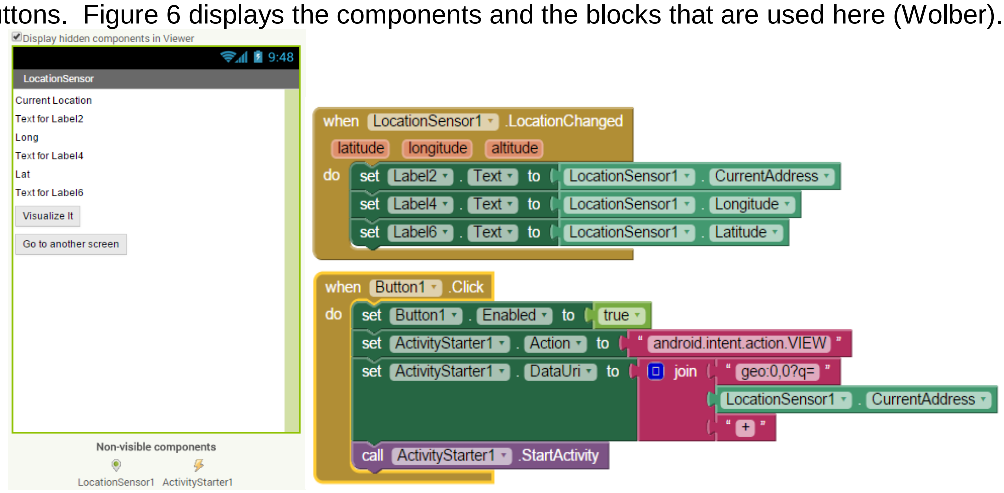

Fig. 6. The components and blocks of part 3.4.

The location sensor calculates and presents the address, longitude, and latitude in the labels. If the user presses the button "Visualize It", the current address will be presented in google maps using an activity starter. The list at the end of the screen allows the user to go to another screen. The list here does a similar function like the control buttons in the previous screens (Android Developers).

4. DIFFICULTIES

There are two major difficulties that may face the reader while using the app for a development. These two difficulties are related to ActivityStarter and App Inventor Companion. As it was mentioned earlier, ActivityStarter is a component that allows running any android app. The difficulty comes, however, from the

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necessity of familiarity with Java Android SDK. Thus, the developer must be extremely careful when dealing with ActivityStarter because the upper/lowercase letters are important while typing its information, for example (Wolber).

The main problem with the companion is that it does not present all MIT App Inventor 2 features at all or, in very few cases, they are presented mistakenly. One solution to tackle this problem is to build the app and install it to a real device to figure out the validity of the design though it is hassle to do so.

5. FUTURE WORK

The first author works for Umm Al-Qura University as a teaching assistant for the Computer Engineering Department, so teaching a course in CPS that implements the proposed ideas of this paper to assess how helpful using MIT APP Inventor 2 is for undergraduate and graduate students is very important whether it is done by the authors or other instructors.

Another planned future work is to release a new version of this app whenever MIT App Inventor is updated especially if the update offers new features to deal with sensors. A great way to get feedback provided by many users could be achieved by sharing this app in google play store.

Two suggestions for the reader and the research community after reading this paper. First, using MIT App Inventor 2 and Arduino controller which is widely used in cyber-physical systems. Arduino is defined as an open-source electronics platform based on ease of use in terms of its hardware and software. It is made for anybody who is interested in making collaborative projects (Arduino). A good tutorial that combines MIT App Inventor along with Arduino is provided in (Santos). Second, MIT App Inventor 2 supports LEGO MINDSTORMS NXT robot. The use of robots in cyber-physical systems is wide spread. Good sources that talk about using robots to teach CPS are (Crenshaw, 2013), (Lawlor, et al., 2013), and (Marwedel & Engel, 2014).

6. CONCLUSION

Currently, an enormous development has occurred in many areas. This fast improvement necessitates coming up with innovative educational tools that facilitate knowledge for students. This paper provides various designs of using MIT App Inventor 2 in a class setting to teach cyber-physical systems (CPS) through dealing with AccelerometerSensor, Clock, Microphone, LocationSensor, and OrientationSensor.

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