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Environmental Health Monitoring with Smartphone Application

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***Abstract* — Environmental health is an important issue today due to the increasing number of people living in urban areas and the threat to human health from various kinds of pollution. It is very dangerous for us to carry out daily activities where the health of the environment cannot be known with certainty. In this research we study, understand, design and develop smartphone applications that can indicate if the environment where we conduct our everyday activities is free from harmful pollution. The measurement of various types of pollution requires a variety of sensors. This study examines which types of pollution can be detected by today's modern smartphones. In addition to pollution observations, today's smartphones also provide sensors that measure acoustic quantities, light strength, and air pressure. The aim of this research is the development of mobile device applications (Android) and external sensors. The applications to be developed are expected to monitor and provide early warning on the environmental health conditions of a place in real-time. People can then avoid places where pollution levels endanger human health.**

Keywords — Environmental health, Smartphone apps, Monitoring

I. Introduction

Environmental health information is difficult to obtain, even in developed countries. This is because of the limitations of physical and chemical measuring device parameters, and the fact that biology is a factor that has the highest effect on the health of the environment. The most common definition of environmental health is that it relates all physical, chemical, and external biological factors to a person, and it relates to factors that impact behavior. It encompasses the assessment and control of environmental factors that can potentially affect health. It is targeted toward preventing disease and creating health-supportive environments. This definition excludes behavior not related to the environment as well as behavior related to the social and cultural environment, and genetics [1]. Meanwhile, according to the law on environmental health, Number 66 chapter 1, article 1, paragraph 1 from 2014, in the Government of the Republic of Indonesia makes "*Efforts to prevent disease and/or health problems from environmental risk factors to realize healthy environmental quality from the physical, chemical, biological, and social aspects.*" [2].

From the above definition, environmental health is very complex. Measuring and monitoring physical, chemical, biological, and social factors is certainly not an easy matter. Physical factors include temperature, humidity, noise, lighting, micro-particles, vibration, radiation, electric fields, magnetic fields, and other radiation. Chemical factors include various types of pollutant gases such as carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and others. Biological factors include microbes, insects, rodents, and animal-borne diseases [3].

To measure the physical and chemical as well as the biological factors, many expensive sensors are needed. This is why access to environmental health information by the public is still very difficult.

Some efforts have been made, such as the collection of data by the World Air Quality Index (AQI) project, in which approximately 3752 sensors over 3000 international cities on five continents were installed. According to information on the official website, every day data is added from the World AQI sensors located in major cities around the world. However, until now, no city in Indonesia has such sensors installed.

One advantage of the World AQI project is that the mounted sensors are very comprehensive and the air quality data can be accessed using a smartphone by installing an application. However, the community of users has to pay some amount of money (1 US$) to be removed from the display ads shown on the smartphone. By paying 1 US$ we could enjoy a pollution early-warning system and even paying 2 US$ to enjoy information services and be warned of the dangers of air pollution would not be expensive.

The lack of a World AQI model means that our smartphone must be connected to its database server. The quality of the network connection and the Internet server become very important. Disorder in the Internet connection or server will result in failure to access the information. Another shortcoming is that the World AQI range of sensors is spatially very limited. Only some areas of towns with potential air pollution have been fitted with such sensors [4].

Other research that provides good news in this area has been conducted at the Centre for Advanced Electronics and Sensors, RMIT University, Melbourne, Australia. Professor Kourosh Kalantar-zadeh [5] has researched sensors that can detect hazardous materials, such as NO_2 gas in air. These sensors can also be embedded in a smartphone. The development of these sensors has been published in an article in the journal ACS Nano [6]. Although the proposals are currently being written (early 2016) so far there no inexpensive and accurate smartphone with an NO_2 sensor has been produced. By using a smartphone with gas sensors everyone could monitor harmful gases from the burning of wood and coal, and motor vehicle exhaust fumes, which are very harmful to human health.

From the explanation above, and addressing the unavailability of information on real-time air quality information in Indonesia, here we propose research to study, observe, understand, design, and create an application that can monitor and give early warnings (alerts) regarding environmental health via smartphones, in particular, the health of the environment as a result of physical, chemical, and biological factors.

A. The Purpose of this Research

The purposes of this research are as follows;

1. To monitor the physical, chemical, and biological factors that affect environmental health and create a device that will give an early warning when the levels monitored exceed a threshold.
2. Support the research carried out at Diponegoro University into the utilization of information technology, in particular, to help improve the health of the wider community.

B. Benefits of this Research

The benefit of this research is that any member of the public with a smartphone would be able to monitor the factors that affect the health of their environment. In particular, those factors that are influenced by: physical quantities including air temperature, humidity, noise, lighting, micro-particles, vibration, radiation, electric fields, magnetic fields, and other radiation; chemical factors including various types of pollutant gases such as CO, CO_2, SO_2, NO_2, and others; and biological factors including microbes, insects, rodents, and other disease-transmission vectors. Monitoring could be carried out anywhere and the results would be in real-time. By knowing the health of the environment, people can decide whether to stay or leave.

C. Research Problem

Based on the background described, the formulation of the problem is;

1. How to generate environmental health information from measurements of the magnitude of physical, chemical, and biological factors and also provide an early warning if thresholds are exceeded?
2. Can the smartphone application generated in this research monitor the health of the environment using the measurements above and provide an early warning if thresholds are exceeded?

D. Literature Review

Modern smartphones are now equipped with various advanced sensors, e.g., accelerometers, gyroscopes, gravity meters, ambient light, microphones, ambient temperature, and barometers. The following is an explanation of the function of each sensor available on modern smartphones:

- Accelerometer. This sensor is always there on every platform and serves to measure acceleration or detect and measure vibration and movement. It is usually applied to detect movements such as a shake or tilt. The most common use of this type of sensor is to automatically change the display screen from portrait to landscape mode. Another use is when playing different types of racing games by tilting the device position.
- Gyroscope. Similar to the accelerometer, this sensor is used to detect the rotation of a device or its movement up, down, left, right, forward, and backward. If the accelerometer is affected by gravity, the gyroscope is not affected by gravity; therefore it produces smoother movements than the accelerometer. These sensors are commonly used for games like Temple Run.
- Gravity sensor. A sensor related to the force of gravity is applied to physical devices on three axes (x, y, z). The sensor works in the direction of gravity whether the device is used vertically or horizontally. An example is the control of a racing game by tilting the screen. Similar to the accelerometer, this sensor is used to detect position only and not gravity as such.
- Ambient Light. This sensor is used to detect the ambient light and adjusts the brightness so the user can see the display more clearly. Adjustments can be set automatically to a comfortable level to reduce eyestrain and tiredness. This sensor is also used by camera-based applications for automatic brightness adjustment.
- Ambient Temperature. This sensor measures ambient room temperature in degrees Celsius but can also be converted to degrees Fahrenheit. Others can calculate the wind and air pressure, and weather conditions, but not many smartphone devices have these sensors.
- Barometer. This sensor measures atmospheric pressure. Sensors embedded in most high-end phones can measure how high the mobile phone is above sea level and improve GPS accuracy.
- External Sensors. To measure the magnitude of the physical, chemical, and biological factors that cannot be measured by a smartphone, we need external sensors. For ease of access to these sensors, they will be made wireless. The physical magnitudes to be measured are temperature, humidity, and micro-particles. The chemical magnitudes to be measured are CO, CO_2, SO_2, and NO_2. The biological factors to be considered are microbes, insects, rodents, and other disease-carrying vectors.

External Sensor

Physical, chemical and biological pollution determinants need to be detected by electronic devices outside the smartphone so that the quantities of pollutants can be measured wirelessly.

Physical-Factor Sensor: Temperature and Air Humidity
The SHT 11 sensor was chosen because of its excellent sensitivity and is shown in Fig.1:

Fig 1. Temperature and Humidity Sensor (SHT11)

Physical-Factor Sensor: Dust Detector PM 2.5 and PM 10
Very small dust particles with sizes 2.5 and 10 micrometers are pollutants that are very harmful to human health. One of the sensors that can detect this very soft dust is GP2Y1010AU0F, so this was chosen and is illustrated in Fig. 2.

Fig. 2. Dust Sensor (GP2Y1010AU0F)

Chemical-Factor : Gas Detector CO
Monoxide gas is produced by motor vehicle fumes, to detect this the MQ 7 sensor was selected and is shown in Figure 3.

Fig. 3. CO Sensor (MQ7)

Chemical-Factor Sensor: Air Quality Detector
Some very dangerous gases, e.g., ammonia (NH_3), nitrogen oxides (NO_x), benzene, alcohols, smoke, CO_2, and other harmful gases that significantly affect air quality can be detected with the MQ 135 sensor. Therefore, this was chosen and is illustrated in Fig. 4.

Fig. 4. Air Quality Sensor (MQ135)

II. Methods

A. Stages of Research

1) Phase I: Literature study and sensor investigations
In this stage, we performed a literature study on available sensors built-in on smartphones. The sensors comprised an accelerometer, gyroscope, gravity meter, ambient light, ambient temperature, barometer, magnetic field, proximity, and GPS. Investigation into external sensors not available on smartphones was also carried out.

2) Phase II: Prototype Design of the Mobile Application.
In this stage, we will design and develop a prototype mobile application in accordance with the specified platform. In year 1, the research focused on observations of various in-built sensors on smartphones and external sensors. The next step will be to design and develop a prototype application on the iOS platform for the Apple iPhone. Year 2 will involve designing an electronic device for additional sensors (external) that cannot be measured with a smartphone and designing applications for iOS and the Android platform. In year 3, we intend to develop applications on the Google Android, Apple iOS, Windows Phone, and BBOS platforms that can read all kinds of sensors, either built-in or external.

3) Phase III: The self-test prototype and deployment of mobile applications to devices
In this stage, we will look at the results of the development of the software and this will be tested using the emulator available in the tool development of mobile operating system vendors (SDK - software development kit), i.e., XCode for iOS and Android Studio for the Android platform. After testing on the emulator successfully without any errors, the application will be ready to be plugged into the smartphone device. The same as in phase 2, here, we will test and deploy the prototype application to an appropriate smartphone platform. In the first year, we will use the emulator on XCode, and in the following year, we will deploy it to Apple devices (iOS), Google Android, and the Windows Phone. If the application is not in accordance with established specifications, the development process can be returned to the SDK development tools and so on until the application runs in accordance with the specifications.

4) Phase IV: Documentation, Reporting, and International Journal Submission

This stage involves preparing the documentation as a report and writing-up the results of the research for publication in an international scientific journal.

B. Locations of Research

This research is being conducted at the Laboratory of Software Engineering, Department of Computer Engineering, Faculty of Engineering, Diponegoro University, Semarang, Central of Java, Indonesia.

C. Model of Software Development

The software development tools used are the Waterfall model and RAD (*Rapid Application Development*).

III. RESULTS AND DISCUSSION

A. Results

1. Observation of Smartphone Sensors

The smartphone sensors observed were for Android, iPhone, Windows Phone, and the BlackBerry. Table 1 shows the results of observations from the four smartphone platforms with the highest specification;

TABLE 1. SENSORS AVAILABLE ON PREMIUM SMARTPHINES

No	Smart phone	MOS	Sensors	Release Date	Comm.
1.	iPhone 6s	iOS 9, upgradeable to iOS 10	Fingerprint, accelerometer, gyro, proximity, compass, barometer	Sept. 2015	Wi-Fi 802.11 a/b/g/n/ac dual-band, hotspot
2.	Galaxy Note 5	Android OS v5.1.1 (L)	Fingerprint, accelerometer, gyro, proximity, compass, barometer, heart rate, SpO2	Agst. 2015	Wi-Fi 802.11 a/b/g/n/ac wifi direct, hotspot
3.	Lumia 950	Windows 10	Iris scanner, accelerometer, gyro, proximity, compass, barometer, sensor core	Okt. 2015	Wi-Fi 802.11 a/b/g/n/ac dual-band, hotspot
4.	Black-berry Priv	Android OS v5.1.1 (L)	Accelerometer, altimeter, gyro, ToF proximity, compass	Okt. 2015	Wi-Fi 802.11 a/b/g/n/ac wifi direct, hotspot

Table 2 shows the results of observation on four smartphones platforms with the lowest specification;

TABLE 2. Sensors on entry level smartphones

No	Smart-phone	MOS	Sensors	Release Date	Comm.
1.	iPhone 4s	iOS 5, upgradeable to iOS 9	Accelerometer, gyro, proximity, compass	Okt. 2011	Wi-Fi 802.11 b/g/n, hotspot
2.	Galaxy Young	Android OS v4.1.2 (J)	Accelerometer, proximity, compass	Feb. 2013	Wi-Fi 802.11 a/b/g/n/a cwifi direct, hotspot
3.	Lumia 520	Windows 8, upgradable to v8.1	Accelerometer, proximity	Feb. 2013	Wi-Fi 802.11 a/b/g/n/a cdual-band, hotspot
4.	Black-berry Z30	BBOS 10, upgradable to v10.3.1	Accelerometer, gyro, proximity, compass	Jan. 2013	Wi-Fi 802.11 a/b/g/n, dual-band, DLNA, hotspot

2. Design of the External Sensors

To ease the use of an external sensor accessible via a smartphone, the sensor device is to be constructed using micro-controllers, physical, chemical, and biological sensors, and Wi-Fi connectivity. The micro-controller used will be Arduino with a Wi-Fi Shield. Fig. 5 shows a diagram of the external device using Arduino and a variety of sensors.

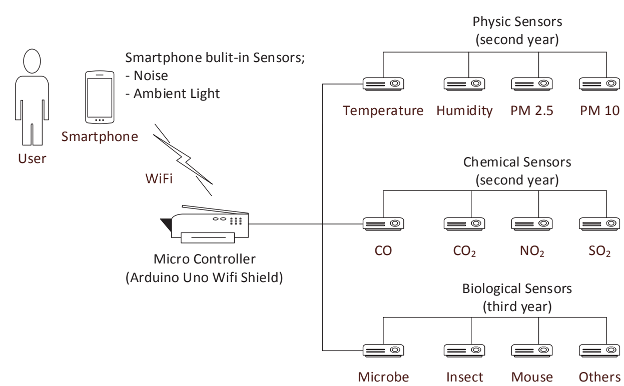

Fig. 5. External Sensors Diagram

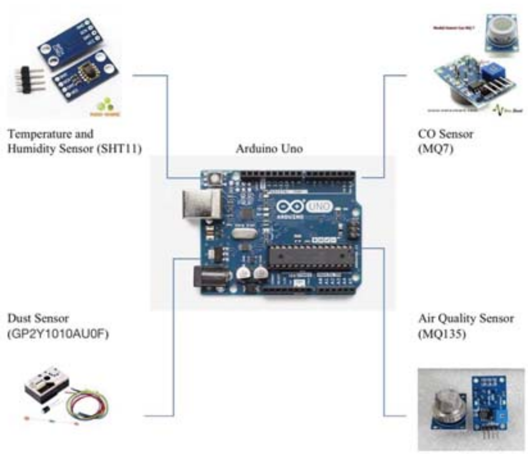

Fig. 6. Sensors External Diagram with Arduino

3. Design of the Smartphone Application

The smartphone applications to be developed are expected to be executed on the Android, iOS, Windows, and BBOS platforms. Users must log in to get all the facilities, including information on the environmental factors and the early-warning threshold levels. A diagram of user interaction with smartphone applications is shown in Fig. 7.

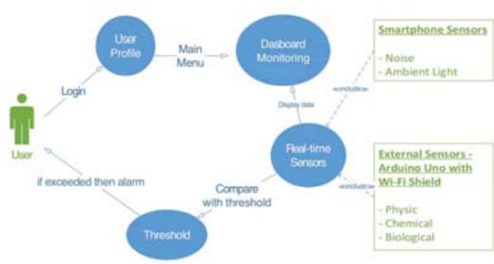

Fig. 7. User interaction with Smartphone applications

4. Design of the Dashboard Smartphone Application

The application development will be carried out using SDK (software development kit). Figs. 8 and 9 illustrate the prototype of this system.

Fig. 8. Smartphone Application

Fig. 9. Smartphone Apps Running on Samsung Android

B. Discussion

Research shows that only two built-in sensors for the measurement of environmental health factors, ambient light and noise (microphones), are currently available in smartphones.

From these results, it can be seen that an external sensor is required. This sensor should be able to measure the magnitudes of all the relevant physical (except noise and light), chemical, and biological factors. Wireless connectivity is required to facilitate easy access to the external sensor.

Until the second years, researchers have developed two groups of external sensors to detect and measure the amount of pollution in physical and chemical factors. Physics group sensors include temperature, humidity, noise, lighting and micro-particles. While the chemical group sensors to measure air quality are carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), ammonia, sulfide and other harmful gases.

The external sensors developed are equipped with Buzzer. If the amount of pollution exceeds the threshold value set then the Buzzer will sound. The sensitivity of each sensor can be set using a variable resistor contained in the sensor.

In the third or final year of the study, sensors will be added to measure biological quantities. This sensor is used to measure biological pollutants, such as bacteria and viruses. Complete research results will be published at the international conference the following year.

IV. Conclusion

The following tentative conclusions can be reached after this first stage:

1. We investigated four smartphones with built-in sensors i.e., iPhone, Android, Windows Phone, and the Blackberry. Observations on fourth platform premium smartphones showed both the class (its most complete feature) and the class of entry (its simplicity) on each platform, which can measure noise and light power as physical quantities. Other physical quantities such as temperature, humidity, micro-particles, and electromagnetic radiation cannot to date be measured by modern smartphones.
2. Due to the limitations of smartphone sensors, electronic devices are needed to install sensors to detect physical, chemical, and biological environmental factors.
3. Research activities have so far focused on observing built-in smartphone sensors and physical-factor external sensors. Electronic circuit device fabrication and sensors to detect chemical factors are planned for the second year of

research. Observations on external sensors for biological factor detection and the manufacture of electronic circuit equipment will be conducted in the third year.

4. An environmental health monitoring application for an Android smartphone has been successfully developed. Test results show that this application functions correctly and in accordance with the initial design.

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