The design and evaluation of a sensor-based mobile application for citizen inquiry science investigations

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Abstract. Despite their advantages of portability and ease of use, mobile devices have not yet been used in their full potential in education to measure and investigate real world phenomena. While some existing applications exploit individual sensors on mobile devices, there is no current toolkit that combines and customises data from the full range of sensors, and makes these data available for import to citizen inquiry science projects. This paper presents such a toolkit, called the Sense-it app, which gives access to all sensors on Android smartphones and tablets and connects to new or existing citizen science projects. We describe the design and formative evaluation of the toolkit in collaboration with students and teachers from a city technology college.

Keywords: mobile phone sensors, citizen science projects, mobile applications

1 Introduction

The idea of having ordinary people act as citizen scientists has become increasingly popular during recent years. Non-professional members of the public can voluntarily collaborate with scientists in order to contribute data to natural science projects such as species identification and air pollution. Citizen science is an inexpensive way to collect large-scale data sets for research purposes and educate the public in scientific thinking. Yet, citizen science is facing challenges in extending to a young population disinterested in science education [1, 2]. Also, most citizen science projects take a top-down approach; apart from data collection activities, they do not engage volunteers in all the stages of the scientific process. The aim of this paper is to address these challenges through the design and evaluation of a mobile application (app), called Sense-it. Sense-it unlocks the hidden potential of smartphones by giving access to phone sensors and it links to a web-based platform (www.nquire.info) which hosts proposed investigations. The concept, design and example applications have been developed through a partnership with Sheffield University Technical College (UTC).

2 The State of the Art in Citizen Science

Citizen science is a term used to describe the research collaboration between scientists and the public in projects such as species recognition and counting, and water quality monitoring. The role of the public is to contribute to research-related tasks such as observation and measurement. The benefits of citizen science endeavours are scientific ("large spatial scales, long time series, data from private land, and labour-intensive data that would otherwise be expensive to collect") and educational including "educating the public in science and scientific thinking, inspiring appreciation of nature, and promoting support for conservation initiatives" [3, p.1]. Participation in citizen science projects could contribute to the demand for STEM proficiency by offering hands-on STEM opportunities to amateurs and boosting their interest in these disciplines [1].

One of the challenges citizen science faces is the perception that citizen science should be a means to recruit people as data collectors or analysts rather than engage them in all aspects of the scientific process. The frequently adopted model for doing citizen science is a top-down one with volunteers serving the traditional purpose of data collection [4]. Having non-professionals devise their own scientific questions and activities is a challenging task, for proposed investigations should be personally relevant, accomplished using recognised methods of data collection and analysis, valid and ethical [5].

3 Mobile Phone Sensing

Mobile phone sensing is a relatively new area of research related to the use of sensors embedded into smartphones, such as accelerometer and compass, and their application to domains such as social and environmental monitoring. Sensors can be organised into: a) motion sensors measuring acceleration and rotation using a 3-axis coordinate system (e.g., accelerometers), b) environmental sensors measuring environmental conditions such as air temperature (e.g., barometers), and c) position sensors measuring the physical position of the phone (e.g., GPS). Sensor-based applications designed explicitly for citizen science initiatives have been developed for the observation of nature such as *iSpot* (www.ispotnature.org), astronomy such as *Meteor Counter* (http://meteorcounter.com/), recording of environmental conditions (e.g., *NoiseTube*, http://noisetube.net/), and social science applications such as the *Community Ethnography app* (www.mtu.edu/news/stories/2013/october/story97909.html).

The main functionality of available mobile apps is to capture nature and wildlife and report on environmental conditions as a means to solve science-related problems. The role of the user is restricted to mainly collect

and upload data to science websites where professional scientists take over and analyse data. Based on the type of citizen science project to be implemented, these applications make use of only a specific number and not the full range of sensors available on smartphones. To the best of authors' knowledge, no sensor-based mobile application has been yet developed which allows users to make use of all the sensors available on their mobile phones, connects sensor recordings to a diverse set of citizen science projects, provides instant feedback on how a sensor recording relates to other users' input, and scaffolds users in proposing and designing their own citizen science investigations. This paper presents the design of such an application, called the Sense-it app (available in the Google Play Store). It can be freely downloaded from Google Play under a 3-clause BSD licence.

4 Design of the Sense-it App

The Sense-it app is comprised of three tabs: the Explore, Record and Share tabs (see Figure 1). The Explore tab is used to preview a matrix of sensors available on a given smartphone. By touching a sensor icon, a graph is produced showing the live recording of the sensor. The Record tab is used to select sensors, manage their sampling rate, record and save data. Users have the option to preview a graph of the data during the period of recording, save and inspect the recorded data**.**

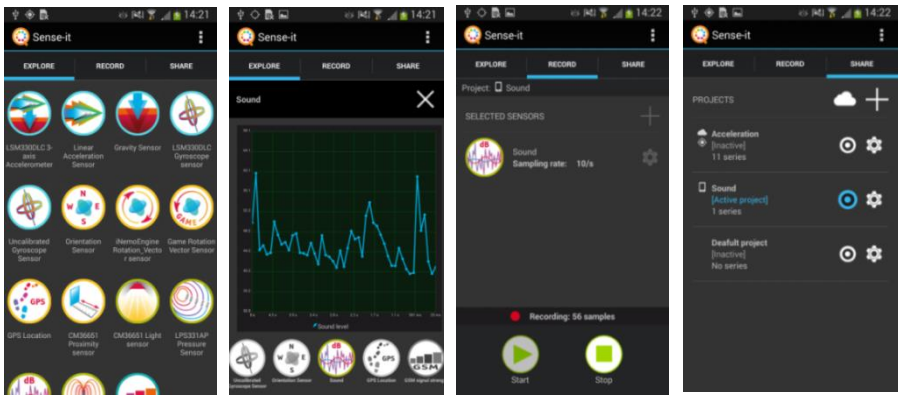

Figure 1. The Explore, Record and Share tab

The use of Share tab is twofold. First, it allows users to create profiles using the sensors selected in the Record tab. Profiles are used to group and save a set of sensors for future use. For example, to map the noise in a neighbourhood, the sound and GPS sensors are selected. The sound sensor captures the level and sound density and GPS provides the location of the

observation. A profile described as 'Noise map'can be created that includes the sound and GPS sensors. This profile is saved and is readily available when users access their application in the future. Second, it enables users to download existing profiles and contribute data to existing investigations by connecting to a web-based platform. Collected data can be uploaded to the web-based platform and automatically processed.

A web-based platform names nQuire-it has been created alongside the Sense-it app. Users can use the platform to propose and run citizen science investigations in informal settings, explore, visualize, and analyse their data and compare it to other users. Post-processing algorithms are applied to calibrate data from sensors, assist in data interpretation and integrate data from multiple recordings into a single plot. Instructions on how to author an investigation (e.g., how to record data using Sense-it) are given to ensure similar data acquisition conditions and improve reliability of collected data. The platform hosts a set of investigations including, 'Noise map' (Sound, GPS), 'How to attract bumble bees in your garden' (Camera, GPS) and 'Are birds scared by noise?' (Sound, Camera, GPS). Future work is underway to create a community of users online who will propose investigations that will make use of the full range of available sensors.

5 Evaluation of the Sense-it App

As a means to engage young people as informants [6] in the design process, we partnered with Sheffield UTC. The role of young people was to evaluate and improve the design of the tools, define the aims and design personally meaningful science investigations. The first prototype of the Sense-it app was evaluated by 96 students (16-18 years old) (Males = 86, Females = 10). Students were formed into 14 groups and they were asked to use and then evaluate the toolkit and propose science investigations that might be implemented using the toolkit. A set of worksheets was given to each group to support and guide their activities. Worksheet 1 asked groups to propose two science investigations by writing down a title, a specific question and how to use the app to collect data. Worksheet 2 asked groups to write down what they like the most about the app, what they like the least about it and what they would like to change on it.

Students' answers were analysed using thematic analysis. The answers were organized in clusters of relevant meaning and reduced into summary categories. The analysis revealed the following themes: (a) In terms of their evaluation of the application, students were found to be satisfied by the potential to customize sensors, the fact that the recording data was presented in two formats (numbers and graphs) and could be saved. Their suggestions for improvements were clustered around: accessibility issues includ-

ing the complex information display on graphs and sensors, difficulty in navigation, the need for simplicity, and attractiveness in terms of colours, sensor icons design and fonts. (b) In terms of the proposed science investigations, these were grouped into the following categories: sound, light, acceleration and temperature. Some investigations suggested by the students are the following: How loud is it when you do Maths compared to English?, How bright does light need to be to wake you up?, What is the acceleration and top speed of the lifts in UK?.

The review of students' proposed investigations revealed that the identification of science investigations that can be easily implemented and of interest to the majority of young people is a rather difficult task [7]. The investigation 'Find the fastest lift' proposed by the students has already been integrated into the Sense-it app. Based on students' recommendations, the following changes were made to the app: depictive icons for each sensor were designed, a help button was added giving a brief description of how each sensor works, and the three tabs of the app were renamed into Explore, Record, Share pointing to their main functionality.

6 Discussion

The development and evaluation of a sensor-based application which combines and customises data from the full range of phone sensors and makes these data available for import to citizen science projects comprised an important step towards engaging young people in doing citizen science. Initial insights from the evaluation of the Sense-it app reveal that young people liked the fact that they can use their phones and tablets to do science as well as the design of a flexible app which unlocks their phones potential.

The active participation of young people to the process of development, evaluation and use of the Sense-it app is an example of how citizen science projects could shift from the frequently adopted top-down model of volunteers serving only purposes of data collection [4]. Young people had the opportunity to negotiate how the application looks like and functions to better fit their expectations. In addition, the flexibility of the application offered young people the opportunityto set up and run their own science investigations and get credit for their contributions by assigning the authoring of each investigation to the person/s who proposed it in the web-based platform. As a final step, new investigations will be revised by experts to ensure young people provide detailed instructions on how data would be collected thus enhancing their quality.

7 Conclusions and Future Directions

We have described a mobile application which uses all the sensors on mobile devices, links to diverse citizen science projects, provides instant feedback on how sensor recordings relate to other users data, and allows users to create their own science investigations. The next step is to analyse emerging learning gains related to the scientific method and evaluate users' understanding of instructions on how to use Sense-it to run investigations and visualize and compare data.

Although initial findings from use with young people revealed that they are interested in using the Sense-it app and defining their own personally relevant science investigations, there still remains an issue of how to sustain their interest and motivate long-term engagement and participation in citizen science activities. Among the mechanisms to be considered in future studies is web 2.0 technologies, for increasing popularity can result in increasing adoption [2], game-based mechanisms such as missions and rewards, and online community creation.

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