Unlocking Smartphone Data for Educational Use in Teaching and Learning Environment

Fuming Shih and Weihua Li

Massachusetts Institute of Technology
(fuming | wli17)@mit.edu

Abstract. We address the challenges of applying smartphone data to improve the experiences of teaching and learning in the university environment. Specifically, we created a framework to collect, monitor and analyze student behavioral data and increase social interactions for educational uses. The framework has three essential components. The first component is App Inventor, a web-based platform with drag-and-drop tools for novices to create mobile apps that collect personal and environmental data. The second component is Reactive Data Store, an intuitive mechanism that connects multiple data sources and automates the tasks for analyzing personal data. The third component is a push notification mechanism that delivers personalized or group messages as the results of the real-time analysis and triggers more actions accordingly. Together, these components will transform people's campus experiences by unleashing the values of smartphone data. Lastly, we introduced the framework to a group of teachers in higher education with a focus group discussion to identify the plausible use cases in terms of performance assessments, pedagogy design and collaborative learning.

1 Introduction

Smartphones today have become the hub of personal information and social interactions due to the wide adaptation in our society. Additionally, a large set of sensors on the smartphone grants mobile applications the capability of providing customized context-aware services to their users. While the ubiquitous nature of smartphones dramatically improves people's daily experiences, we have barely seen the same effects in the learning or teaching environment. Today, teachers deem the uses of smartphones among students more as a distraction than a companion for learning [10].

The term "mobile learning" captures the essence of what researchers envision that mobile devices will change students' learning experiences. Many initial efforts for mobile learning emphasize the benefits of introducing new interactions or timely contents to mobile devices owned by the users [7, 1]. However, such applications are restricted by the physical factors of mobile devices like computational power, screen size, and connectivity speed. Most importantly, it falls short at marrying the new social norms brought by smartphone uses with traditional pedagogical practices in today's residential campus. Teachers lack effective tools to evaluate students' acceptance of the new knowledge while struggling to keep students' attention in class. On the other hand, students require helps to bootstrap their cooperative learning experience due the lack of social skills in the younger generation. For example, some freshmen may have troubles in finding their study mates after the teacher assigned a group projects. To address this issue, we first need to understand how students behave during classroom hours and then monitor different social situations in the campus environment in order to adjust the course tailored to meet students' needs.

Personal data as well as sensor data on the smartphone can be valuable in understanding people's behavior [6]. For example, by analyzing one's location and accelerometer data, we can tell his or her mobility patterns during the day. With the similar data from a group of people, we can model the group dynamics within a class of students. By reading the information of Bluetooth scans for near smartphones, we can trace the formation and the activities of the friends circle. Together with location data, we can tell where and when students get together to study. We can also monitor the attendance rate of different classes by adding the class schedule published by the administrative office. Although the potentials of smartphone data are great but they are mostly collected in silos by different mobile apps. Even if one determines to collect his or her own data, the data are not easily accessible by people without some sophisticated knowledges and advance programming skills. Furthermore, collecting and using smartphone data can pose great privacy risks to the data subjects if not done appropriately.

Our work is motivated by the need of the tools that help students or teachers utilize personal contextual data to improve their on-campus experiences. To achieve that goal, we introduce four principles to *democratize* the uses of personal contextual data on smartphones: 1) each person should be able to create and customize their own app easily, and 2) collect and manage their own data, then 3) configure how they want to interact with the data, and lastly 4) control how to share their data. We present a toolkit called *Personal Context Toolkit*. The toolkit contains three components and they are implemented with the aforementioned principles:

1. App Inventor: A web-based platform that allows the novices to create mobile applications with simply just drag-and-drop actions. Specifically, the coding platform provides modules for reading sensor data and personal information on the smartphone.
2. Reactive Data Store: A cloud-based personal data store that provides an intuitive interface for users to monitor changes in their behavior through data automation. The user can create *triggers* attached to specific data sources or the combinations of them and activate follow-up actions automatically when changes occur in the dataset.
3. Push notification: A real-time mobile messaging system that delivers data with payload to individuals or selected groups of people. In addition, the integration of push notification component in App Inventor allows the developers to customize app's behavior in response to the received messages.

2 Motivating Scenarios

We use a hypothetical scenario to illustrate the challenges of designing an effective learning environment in the university campus today. Specifically, the scenario sketch out educators' efforts for monitoring student progress in class and the difficulties they face.

James is a responsible young lecturer in the local college and he has the passion to improve the students' learning experience in the campus. He is in the process of designing a new curriculum for his newly assigned class, physics 101. It is one of the institutional requirements for all incoming freshmen. Physics 101 has the long reputation as boring and ignoring students feedbacks.

Many college students are addicted to their smartphones. They have come to rely on smartphones for almost everything, ranging from note taking, studying, event scheduling and many more. James recognizes this trend from the past experience and worries that students were missing out on valuable material during class. Some professors in the department have instituted their own mobile phone policies, such as banning the use of smartphones in the class. He doesn't want to follow the same policy and he will like to integrate the use of smartphones in classroom learning.

Turning smartphones into an educational opportunity is the ultimate goal. He plans to have the students solve the problems collaboratively shortly after teaching the new physics concepts. He needs some mechanism to keep track of each student's interaction with others, which is a good indicator for students' engagement level [3] and performance. In addition, he also wants to be informed of the real-time status during the breakout session. For example, he can observe that some students don't pick up the new concepts well if half of the students in that group were inactive during problem solving, or some students are busy checking his Facebook updates while not participating the group discussion. James wants to notify those students if they have been checking with smartphone too often in the class. This is particularly helpful for the distracted students to get back on the classroom learning without being too direct. Conducting surveys and getting the feedbacks in the same day is also what he wants as well. Under such, he can act quickly to modify course materials according to student feedbacks but not wait until it is too late.

James is actively looking for a solution to meet his needs above. He has asked the IT department to develop an mobile app which keeps track and monitor students' behavior, upload the data to remote cloud storage, receive push notification, and pop up surveys for collecting feedbacks; The IT department replied back that the project will take months. He also thought about hiring an outside help, but he doesn't have the budget for that. James is left with the option to develop the mobile app which is not feasible because he has little experience in programming.

2.1 Proposed Solution

Imagine instead of depending on programming experts, James uses Personal Context Toolkit to create his mobile app and invites the students in his class to collect their own data using the app. It markets as to improve their overall learning experience. He finds that App Inventor platform already has all the components and blocks he wants, including sensor probes to read students' contextual data and a upload enabler that sends smartphone data to Google Drive cloud storage and also stores the data as spreadsheets. By just drag and drop the blocks, James now has a mobile app ready for his class. To much of his surprise, the Reactive Data Store can be configured such that it will actively monitor changes in the aggregated data and trigger further actions. He writes a simple script to receive a notice when more than 1/3 of the students are not paying attention to his lecture (e.g. observing the screen status data to know how often the smartphones are used). James can also collect student feedbacks immediately after each class using the survey component. Not only does James find the toolkit useful, many of the students invent creative ways to interact with their own data. For example, some students create scripts to tweet their current status automatically when they are late for the group discussion or TA's recitation, others use the script to get reminders when they become too busy on Facebook during the class.

3 Implementation

We implemented the Personal Context Toolkit to help the individuals collect, monitor and share their personal contextual data. The toolkit is composed of three major components: the App Inventor, the Reactive Datastore, and the push notification mechanism. Figure 1 shows the architecture and the data flow within the whole system.

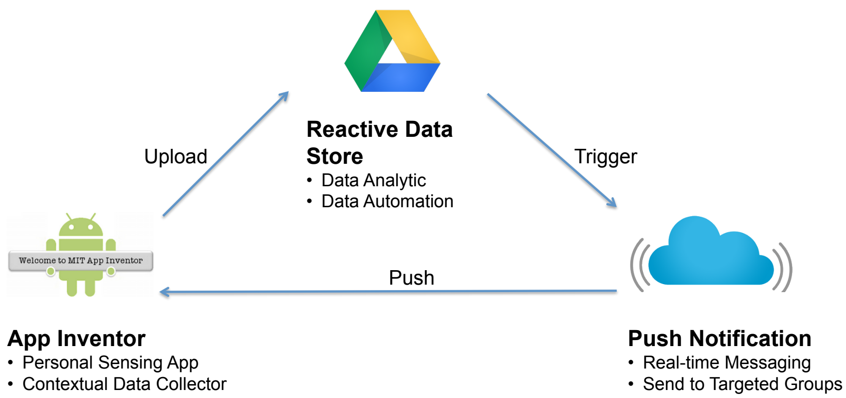

Fig. 1: Personal Context Toolkit Architecture

Table 1: List of components in App Inventor for collecting personal data

Sensors		Cloud Service
Activity Sensor	Battery Sensor	Map
Call Log History	Cell Tower Probe Sensor	Google Drive Storage
Light Sensor	Location Probe Sensor	Dropbox Storage
Pedometer Sensor	Proximity Sensor	Survey
Running Applications	Screen Status	
SMS History	Social Proximity Sensor	
Telephony Info	Wifi Sensor	

3.1 App Inventor

Smartphones are open and programmable. However, the development cycle of a mobile app often takes days, or even weeks for beginners. App Inventor [11] is a free, open source and Web-based development platform for users from all levels, including beginner with no prior programming experience to create mobile applications easily. A user can drag and drop graphical objects on the interface editor to design an app or implement behaviors with graphical blocks. App Inventor also provides many high-level components for using smartphone resources as well as communicating with external resources. For example, it has components for reading the GPS location sensor, taking photos with the camera, receiving SMS texts, and sending Twitter messages. By hiding most of the technical details, App Inventor gives its users the benefits to focus on designing app behaviors rather than lower-level debugging. App Inventor is being used in a variety of educational settings, including classrooms ranging from elementary schools to universities, vactional trainnings and after-school clubs. App Inventor is even beings used to foster entrepreneurship. Entrepreneurs are also taking the advantage of the ability to fast prototypes of their ideas and present the works to venture capatalists, or even consumers.

For the Personal Context Toolkit, we provide an extended version of App Inventor with additional components and user interface elements powered by a new set of sensors for personal contextual data, Google Cloud Messaging (GCM)[1] for receiving push notifications, Google Drive for data storage, and Survey for feedbacks. The new components for collecting personal contextual data are shown in Table 1. In the motivating scenario, James can use the Google

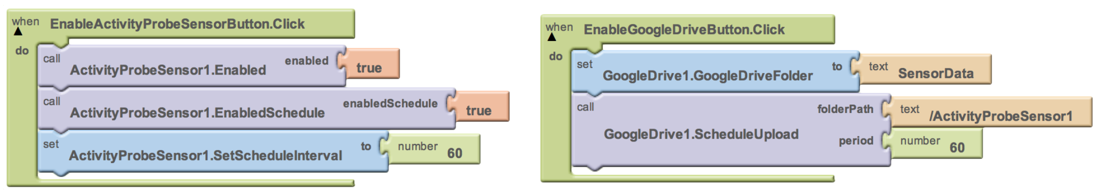

Fig. 2: Activity Probe Sensor and Google Drive Setup

Drive component to upload the activity and screen status data to the Reactive Data Store. He can drag and drop the graphical objects with blocks as shown in Figure 2 to set up the Activity Probe Sensor and Google Drive components. Some of the personal contextual data, such as learning experiences and feelings that Jamess students gone through can't be directly obtained from the smartphone sensors. For example, James can use the Survey component to understand students' cooperative learning experience every time after they just finished a group study. The gathering of a group of students can be detected by the sensing the nearby Bluetooth-enabled devices [2].

3.2 Reactive Data Store

Data automation and analysis are the two major features for the Reactive Data Store. Data automation gets and edits different formats of data from multiple sources, such as personal cloud storage, or files in the shared cloud. The data automation part is accomplished by Google Apps Script [2], which is a cloud based scripting language. Once the personal contextual data is uploaded to the Google Drive, the App Script will be automatically executed and compute the data to produce analytic results accordingly. For our toolkit, we have developed a master

[1] http://developer.android.com/google/gcm/index.html
[2] https://developers.google.com/apps-script/

template using App Scripts for users that includes the following functionalities: search file in the cloud storage, real-time file changes notification, copy file from one source to another, get values from define row and column in the data, set up formula to analyze data, send GCM message, and more event based and time based triggers.

With data automation, we can do many data analysis, such data monitoring, data matching, and visualization on the scheduled basis. In the motivating scenario, James interested in knowing how often each student interacts with other in the group discussion. He can first set up triggers to monitor files and call formulas to analyze the data. He can set up different formulas to keep track of different data sets, like average for the activity data, maximum occurrences for screen status, and frequency for the locations visited as shown in the Figure 3. The result from these different analysis on multiple sources can be aggregated into one place for further analysis. The Reactive Data Store is designed in the way that not only for personal use, but also can act as the data aggregator for a group of users. This is ideal for James because his students can opt-in to share their data or data analysis to the same Reactive Data Store. We can view the Figure 3 as the subset of the aggregated cloud. The aggregate cloud could ask each individual to compute different tasks and report the results back to the aggregated cloud. This is particularly helpful for the group data analysis since James can have a chance to focus on contrasting and combining results on each students performance base on the results. The reactive data store can help to discover the stories behind these data, but helping the users, like James to make informed decisions in real-time in the classroom will be the final goal for this toolkit.

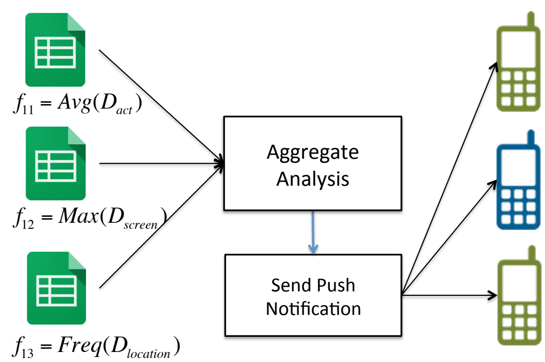

Fig. 3: Activity Probe Sensor and Google Drive Setup

3.3 Push Notification

Push Notification is good at cutting through the noise and delivering the useful information to the hands of the people that want it. As in Figure 3, Google Cloud Messaging can push message to specific users in real-time. For instance, some of James's student were very active during the problem solving session (the green smartphones), but some of them were not (the blue one). James can send different messages to different groups based on the data analysis. As shown in Figure 4, James can use the GCM component to receive the message and then create a notification to alert the smartphone owners upon receiving the message; it is also done by drag and drop the corresponding components and defined the blocks behaviors. The message

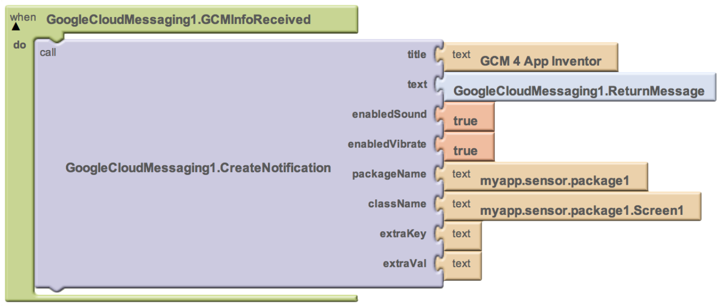

Fig. 4: Google Cloud Message and Push Notification

is a lightweight data package, so we modified the message in the way that it can serve as the action command for the App Inventor components. With this, Jamess mobile app can start up the surveys he defined using the Survey component when the app receives the message with the corresponding command in it. In this way, the push notification and surveys can drive students participation and engagement. This could even improve the learning experience if James got informed a problem from students and he acted quickly.

There are many push notification servers or services in the market that also utilize the Google Cloud Messaging. James also have the option to set up his own since the GCM server code and the setup instructions are included in the our toolkit as well. With push notification, the Personal Context Toolkit can light the spark to create meaningful mobile experiences because it leverages the smartphones as the unique channel.

4 Discussions with Teachers in Higher Education

The access to personal contextual data on the smartphone offers a new way to monitor personal behaviors and group interactions. These data can be valuable for the educator to assess student performance especially their course engagement [5]. The continuous data streams generated from sensors or other apps on each student's smartphone collectively represent their overall in-class and on-campus experiences. Previous research shows that smartphones have great potential for behavior-change interventions in different areas such as promoting well-being [8] and emotion control [9]. Similarly, Personal Context Toolkit aims to give the control or ownership of personal data back to people and allow them to jointly contribute data for improving their learning experience. To the best of our knowledge, Personal Context Toolkit is the first system that allows the users to easily build sensing apps to collect their contextual data and interact directly with the data.

In order to understand how educators will use Personal Context Toolkit (PCT) to improve on-campus learning experiences, we hosted a focus group discussion with 12 teachers from both colleges and high schools. The goal is to understand the current situations in the campus and identify the opportunities for using Personal Context Toolkit to introduce novel pedagogical practices. We asked the participants about new applications that can be accomplished by PCT. We identified three categories of applications from the teachers' responses. The first one is to use PCT for monitoring student behaviors that affect their academic performance. One teacher pointed out that some students develop problematic behavior such as sleeping late or hard to concentrate during the lecture like those in the aforementioned scenario. The real-time push notification provided by PCT can intervene and change their distracted behavior. The second kind of applications address the social issues in today's campus such as bullying or peer pressure. For example, by monitoring activity data from a group of students, the teacher can observe whether there exists a healthy group dynamic or some students are being isolated. The last category is about customizing course materials according to students' progress. For example, the teacher can collect feedbacks from the survey after each class to assess student understanding and change the speed or contents in the next lecture if needed.

5 Conclusion

As the amount of smartphone data explodes, there is a great opportunity to help students or teachers utilize these data to improve their on-campus experiences. We have demonstrated the Personal Context Toolkit as the ultimate solution. The toolkit has delivered the following promises: 1) each person should be able to create their own app easily, and 2) collect and manage their own data, then 3) decide how they want to interact with the data, and lastly 4) control how to share their data. Three components in the toolkit, App Inventor, Reactive Data Store and Push Notification together implement the principles. Personal context and smartphones are converging to shape the traditional on-campus learning and deliver new pedagogical practices.

6 Future Work

To take advantage of the growing open contents on the Web, Personal Context Toolkit need to integrate external resources such as the linked data cloud. We are implementing and experimenting the Linked Data component in App Inventor to query for educational linked data [4]. For example, by consuming the course schedule published by the administrative office, we can build an app to monitor students' behavior of "shopping for classes" at the beginning of the semester.

Within the Reactive Data Store, we are working on a modular, highly configurable data visualization framework for easy data automation and data analysis by adapting the most current technologies, such as Google Chart[3]. The data visualization framework will have a rich gallery, ranging from simple scatter plots to hierarchical treemaps. These charts are suitable for representing the personal data, such as line chart for the activity level trend, column chart for comparing the activity level between yesterday and today, and pie chart for weekly activity level overview. The framework will also be able to connect the data in real-time even they are using variety of data connections and sources, so the visualization charts will be

[3] https://developers.google.com/chart/

updated automatically. The visualization framework also provides a channel for the users to know the list of the apps that opt in to collect data, the types of data that each individual app collects, the date content and the stories behind the data. Overall, these should be an all-in-one solution. People who use the Personal Context Toolkit don't need to set up the web server, data store, analytic server and etc. Once the android application package file (apk) built from App Inventor is installed, all the services are set-up for uses.

Privacy issues will be treated with much higher priority in our framework. We will implement more fine-grained access controls for people to decide how to share their personal contextual data as well as logging all the accesses to the Reactive Data Store for detecting misuse of personal data. Currently, we don't have a formal evaluation of the proposed framework, but we are planning to conduct one shortly. For the coming evaluation, we will mainly forcuse on the case studies. We are going to teach a class for people who are interested in using the Personal Context Toolkit and the case studies will come from there.

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