ROUNDS

Final Report

ECE 1778 – Creative Applications for Mobile Devices

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1 Goal & Motivation

1.1 Background

Approximately 2.7 million people are hospitalized each year across Canada (in 2013-2014) with ~945,000 of these hospitalizations in Ontario alone [1]. While in hospital, patients must be closely monitored by nurses and physicians (clinicians) to ensure the effectiveness of medical interventions and that their recovery is progressing as planned.

Monitoring a patient's health status involves gathering both qualitative and quantitative data. Qualitative data includes inquiring about how a patient is feeling, whereas quantitative measures include taking numerical vitals measures.

Vitals measures provide healthcare practitioners with an objective measure and are a crucial part of ensuring a patient's normal homeostasis, with abnormal readings potentially indicating pathology [2]. There are four traditional vitals measures that are commonly taken: Pulse rate, respiration rate (rate of breathing), blood pressure, temperature and in recent years, blood oxygen saturation (O2 Sat. %). Due to their importance, vitals are frequently measured as part of general checkups and multiple times per day (or per hour) for patients in an acute care setting such as a hospital.

1.2 Motivation

In many hospitals, vitals measures are still done primarily by hand [3]. Vitals monitoring systems exist, however these systems cost thousands of dollars and the results outputted are often still recorded on paper notes (for example, in a patient binder). Fig. 1 on the following page illustrates an example patient chart where nurses, after taking a patient's vitals, will plot (by hand) the measurement trends over time. This process is both time consuming and creates the opportunity for additional transcription errors. This binder grows throughout the patient's stay and is referred to periodically by physicians. The lack of any built-in "intelligence" however, means that catching any abnormal trends relies solely on the physician's attentiveness.

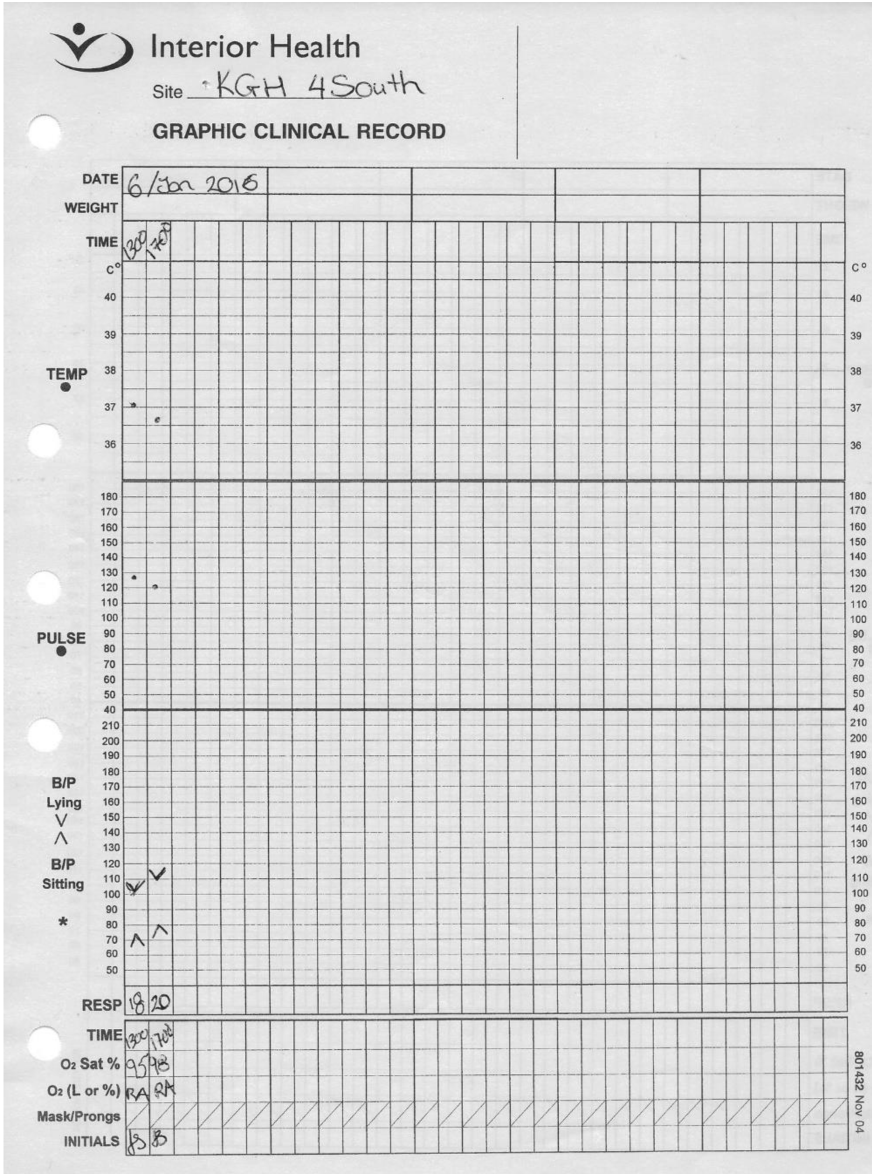


Figure 1 - An example of a typical patient vitals chart

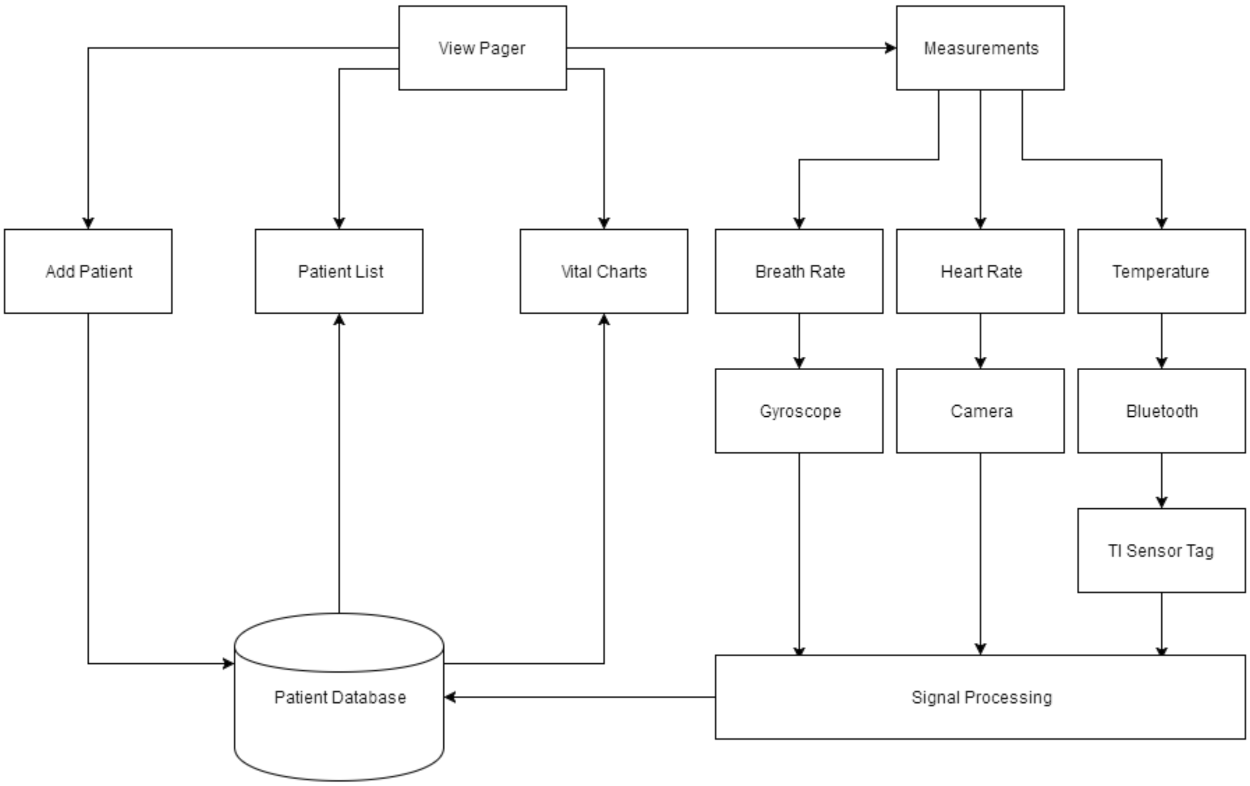
1.3 Goal

The current process can be improved by providing a fast, effective and simple way for nurses to measure, record and visualize a patient's vitals electronically. This would increase the efficiency of measuring vitals as well as improve speed and reduce potential transcription errors. Additionally, by digitizing these measures, any abnormal readings or trends can be identified quickly and effectively with the aid of computing.

Our app is capable of measuring, visualizing and storing three vitals: Respiratory rate, heart rate and peripheral body temperature.

2 Overall Design

2.1 Block Diagram



2.2 Application Workflow

The block diagram in section 2.1 provides a high-level overview of the functional blocks in the application. The **View Pager** block handles the general user interface, which allows users to navigate through different functions of the app, such as the **Add Patient**, **Patient List**, **Vital Charts**, and **Measurements** tab.

Add Patient provides and creates a new patient in the database, which could be accessed through the Patient List block to select, view and edit each patient.

Vital charts blocks takes all vital measurement stored in the database for one patient and plot the data versus time to provide a visual of the vital trend.

Measurement block contains the three vital measurement tab (Breath Rate, Heart Rate, and Temperature). These measurement classes will communicate with their sensor respectively (Gyroscope, Camera and TI SensorTag).

All the raw data from the sensors are sent to a **Signal Processing** block for filtering and compute the vital measurement, which will finally be stored back into the patient database for access from other blocks.

3 Statement of Functionality & Screenshots

3.1 Technical Details

3.1.1 Application Environment

The application is targeted to work for android 5.1.1 API version 22, while requiring a minimum SDK version of 19.

3.1.2 Databases

SQLite is used for the database for saving the patient list information and three different types of vitals readings for each patient.

3.1.3 User Interface

The overall design for the App is to use only one layer for easy understand and access by using a **ViewPager** for the framework/structure. Patient **ListView** with name filter and NFC provides easy access to finding patients. The **TabHost** makes measuring/graphing the vitals intuitively easy while using only one page of the **ViewPager**. The measurement GUI allows feedback to the user while measuring different vitals.

3.1.4 External Libraries

Apache POI HSSF	To export Excel files from the database for vitals data
MPAndroidChart	Library used to generate vital charts from vital data
CustomGauge	Temperature UI Gauge
NDefTools	NFC library

3.1.5 Sensors

Android Gyroscope	To measure the angular velocity for the respiratory rate
Android Camera	To detect the color pigmentation due to one's pulse for heart rate
TI Sensor Tag	To find the surface body temperature
NFC Sensor	To find patient profiles quickly (Not Required)

3.2 Add Patient

The "add patient" screen shown in Figure 2 is where the nurse can enter the details of their patient including name, date of birth and health card number. Here the nurse can also register a patient's Near Field Communications (NFC) armband so it is tied to their profile.

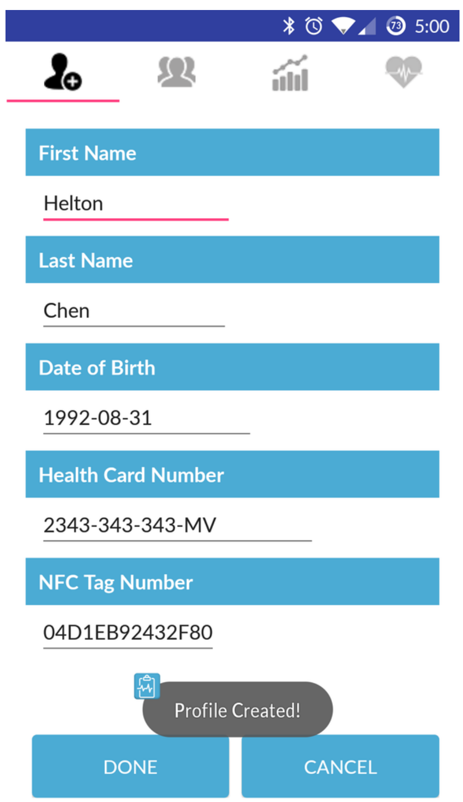


Figure 2 - The Add Patient screen with confirmation toast

3.3 View Patient List

This screen (Figure 3 below) provides a list view of all a nurse’s patients, with a few identifying details for each patient. There is a search bar at the top that can be used to filter the patient list. Feedback such as highlighting indicates that a patient has been selected. Additionally, if a patient has a registered armband the nurse can simply tap the phone on the band and the phone’s NFC reader will detect and select the corresponding patient automatically.

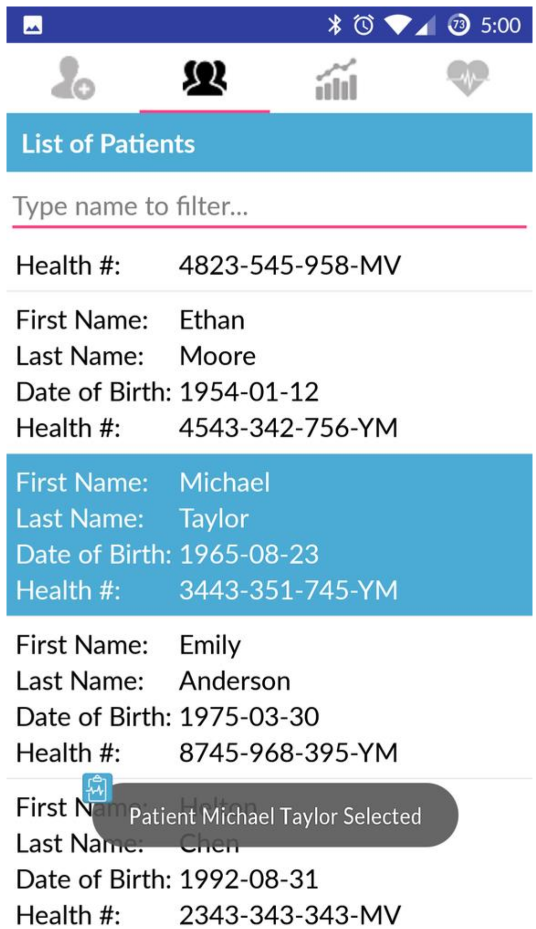


Figure 3 - The patient list showing a selected patient

3.4 View Patient Vitals

Figure 4 shows the patient vitals charts view, where the patient's historical measurements are displayed. There are three sub-tabs (at the bottom of the screen) – one for each of the three vitals measures. To enable nurses to more effectively identify problematic trends in a patient's measures there are two horizontal red lines displayed on each of the graphs, which correspond to the upper, and lower normal bounds, any readings that fall within this range are considered normal. These bounds are set depending on age and gender and so will differ from patient to patient correspondingly. For instance, the range of normal heart rates will decrease with age.

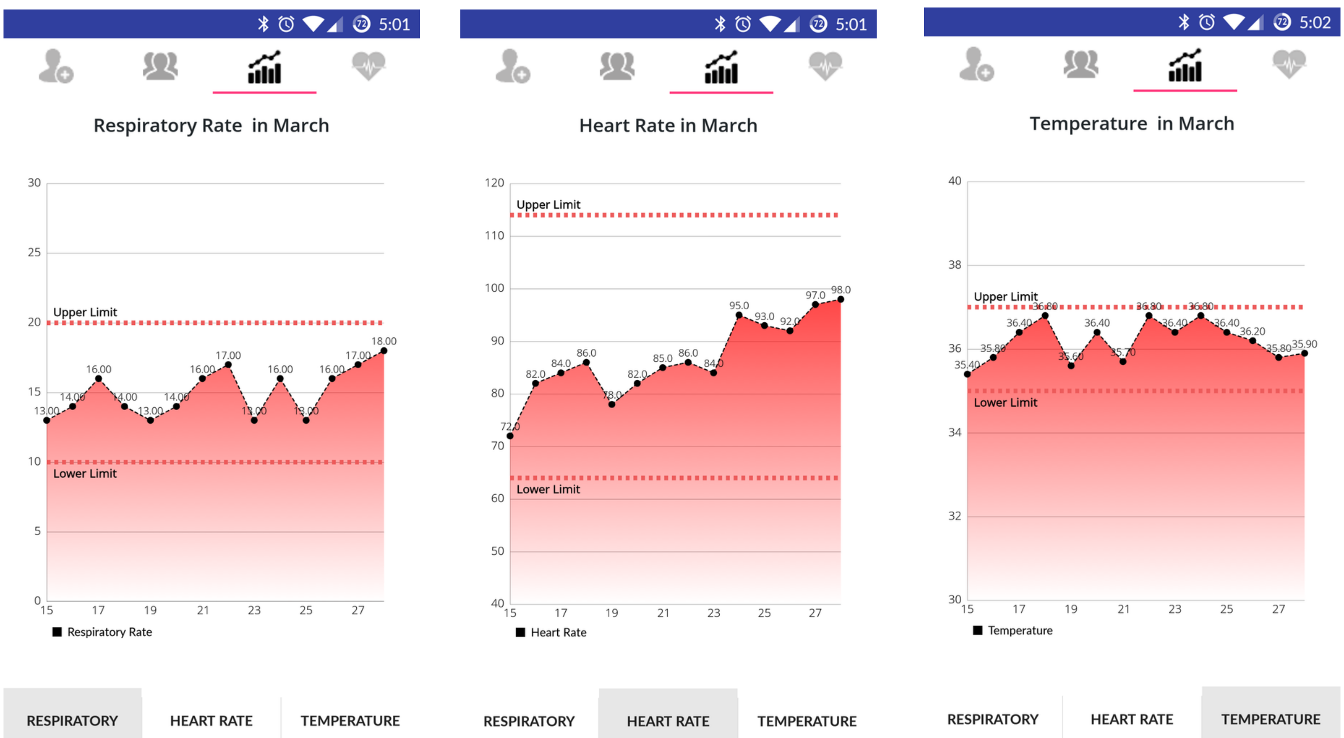


Figure 4 - Historical vitals measurements for (left to right) a) Respiratory rate, b) Heart rate, c) Temperature

3.5 Add New Measurement

The three measurement sub-tabs are where a nurse is able to measure a patient's vitals in the app. Shown below (in Figure 5), is an example of the animations provided for each vitals measure. These are synched with the real-time readings to provide feedback to users while measurements are being taken.

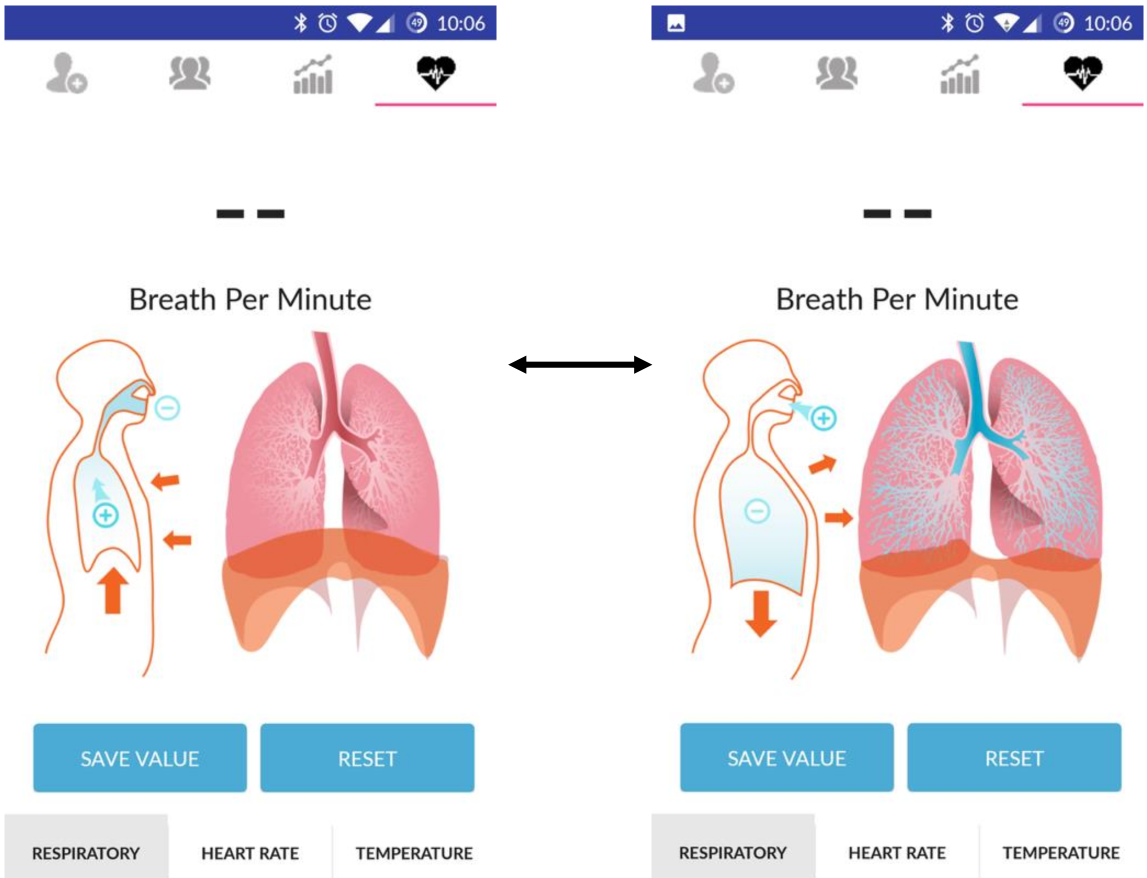


Figure 5 - The two animation states that will alternate in time with respect to patient's exhalation (left image) and inhalation (right image)

For heart rate, the phone's camera and flash are used to detect the minute changes in colouration of the finger, which correspond to blood pulsating in time to the heart beating. Figure 6 shows the animation feedback (grey and red heart icon).

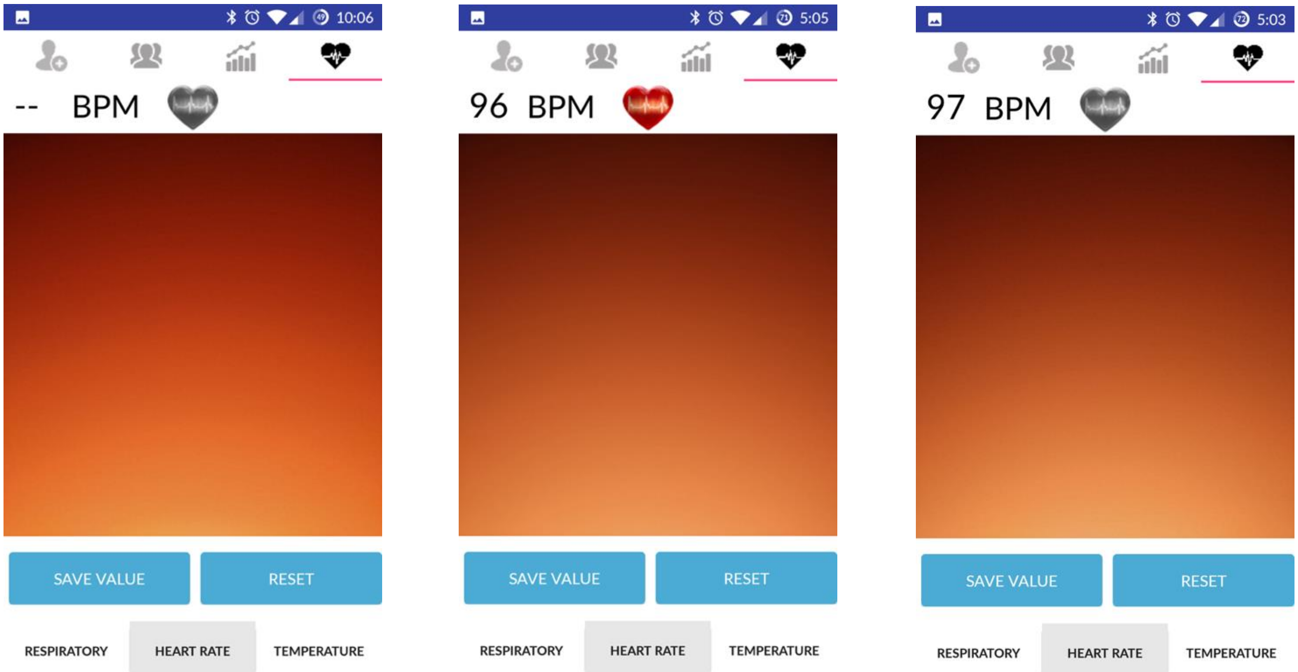


Figure 6 - The heart rate measurement screen showing the animation feedback (left and centre images) and the measured value (right image)

To record peripheral body temperature, the phone must connect with a Texas Instruments (TI) Sensor tag with built-in infrared temperature sensor, which takes peripheral body temperature readings. This process is shown below in Figure 7.

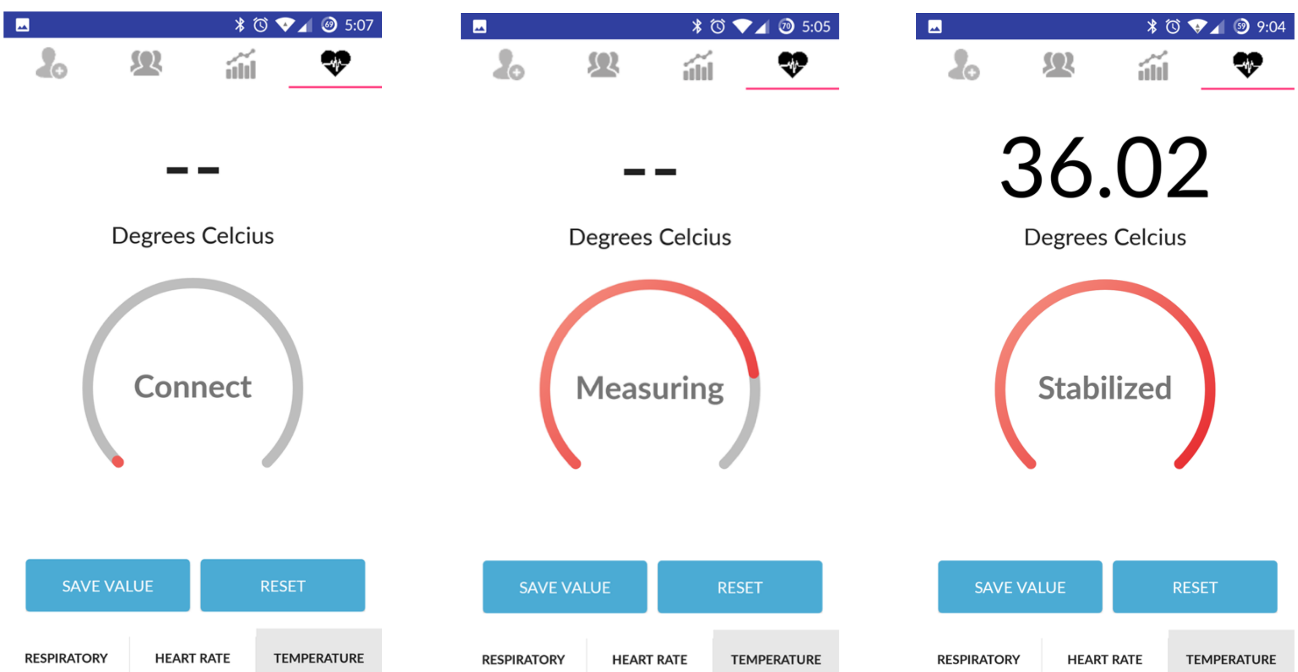


Figure 7 - The temperature measurement screens showing (left to right): a) Connecting to the TI sensor tag, b) measurement progress, c) Stabilized reading

Respiratory rate is measured using the phone's internal gyroscope, by measuring chest rise and fall during their breathing motions. After a final reading has been measured and calculated, it is displayed large and visible near the top and centre of the screen. The user then has the option of either saving this value or resetting the value to begin taking measurements again (e.g. if something went wrong when the value was being measured). Note: The phone will continue to take measurements and will automatically update the readings, even if reset is not pressed.

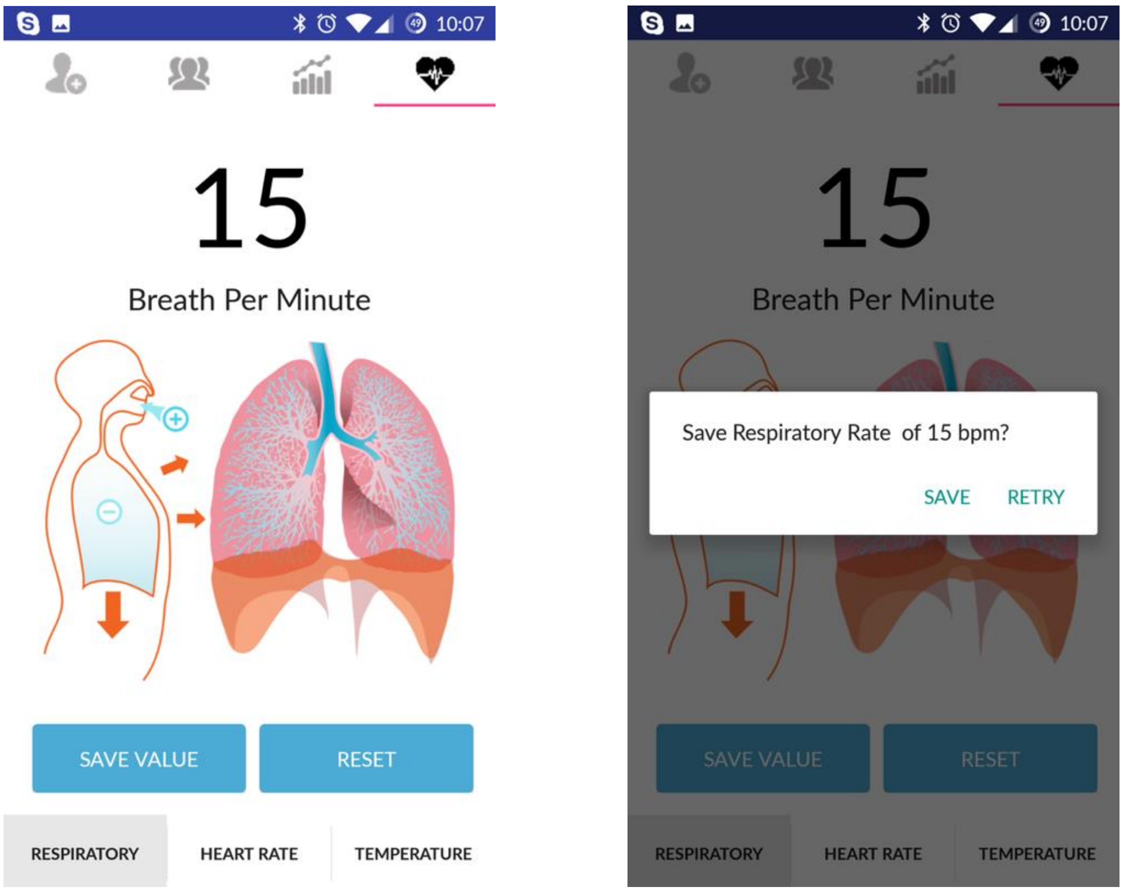


Figure 8 - The final measured value is displayed prominently (left image), and prompt message before the value is saved (right image)

When the save button is pressed, a confirmation box prompts the user to confirm the value that will be saved (shown above in Figure 8). The saved values are stored in the database and will be displayed on the corresponding patient's vitals sub-tab.

3.6 Abnormal Reading Warnings

It is important to augment nurse's abilities to identify abnormal trends in a patient's readings, and differentiate these from false-positives (e.g. something happened during measurements creating large artifacts in the signal).

The app enables this in a number of ways: on any of the three vitals measures sub-tabs a reading that is outside normal physiological parameters will be displayed in red. When the save button is pressed the normal confirmation pop-up will be replaced with a warning pop-up indicating that the reading is abnormal (shown below in Figure 9). Another way is in the historical chart view where, as mentioned, two horizontal red lines are displayed for the upper and lower normal range bounds – it is clear to see if a measured value falls outside this normal range.

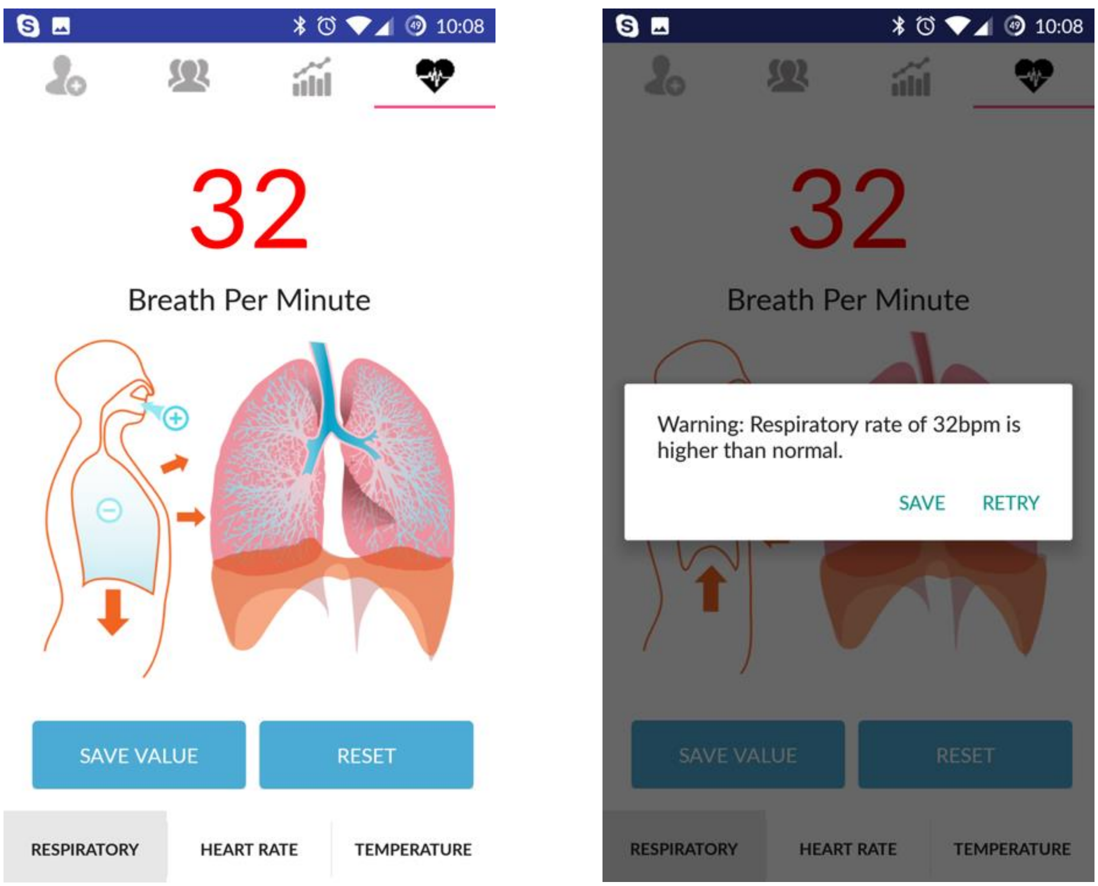


Figure 9 - Abnormal readings displayed in red and warning prompt instead of normal save prompt

3.7 Export to Excel & Share

Healthcare is a fast paced and data intensive industry, therefore compatibility and interoperability were other important design considerations that had to be taken into account. There need to be an easy way to share the information collected and stored by the app in a commonly accessible way.

To provide this functionality, there is an export function which is accessed from the patient list menu by a long-press on a patient's name. This opens an additional options menu allowing users to:

- Save the patient's data to an excel file
- Export and send it
- Delete the patient

As seen in the screenshot in Figure 10, there are numerous ways provided to send the data, including E-mail and Dropbox.

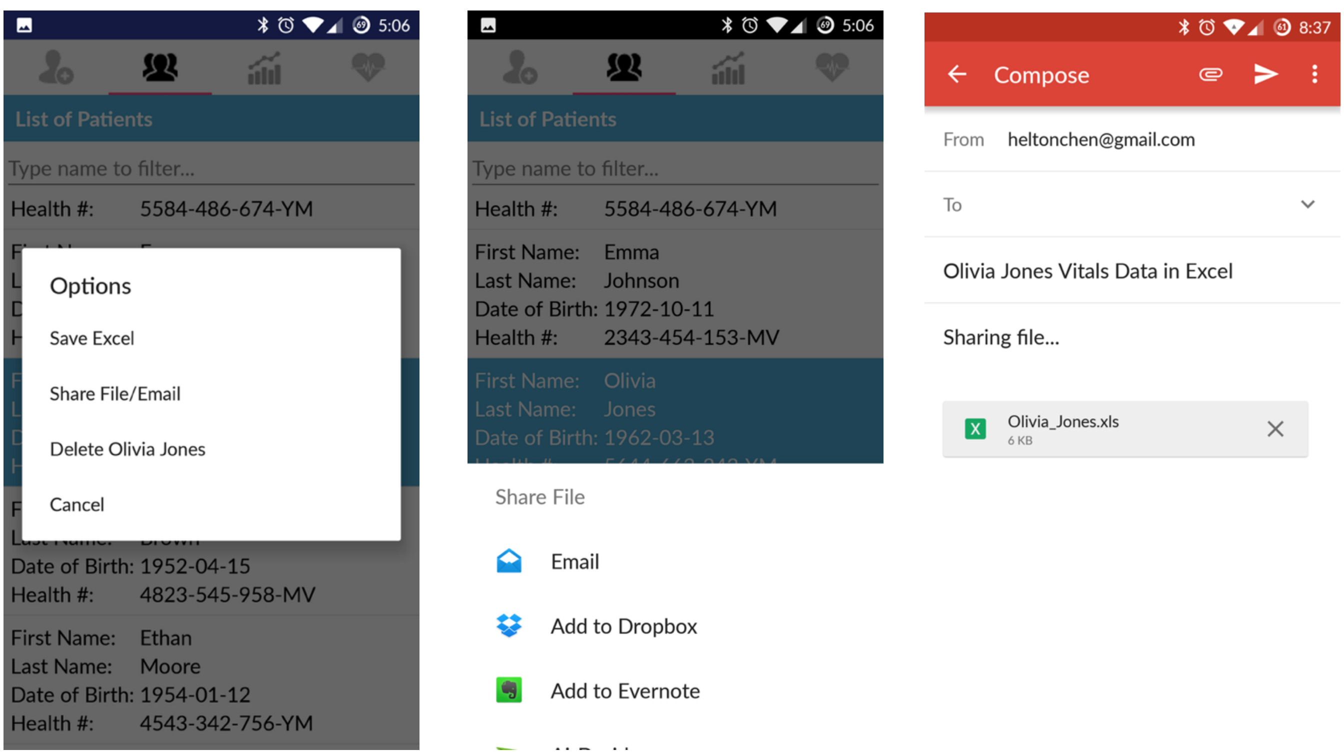


Figure 10 - Exporting a patient's vitals data via email

4 What Did We Learn?

4.1 Specialist

Over the course of this project, I learned a great deal about working with a team of developers and how to communicate my clinical expertise in a way that those unfamiliar with the field could understand. I also learned the challenges and practical aspects of using sensors for physiological measures and a bit about the algorithms and signal processing from my teammates. One thing I would do differently would be to identify useful (i.e. open source with APIs) sensors more quickly – there are a multitude of different sensors available, however the majority of them are proprietary (being tied to specific companion apps). I feel that I wasted a lot of time initially researching many possible sensors and their capabilities only to keep finding out that the data they collect was not accessible to outside parties.

4.2 Programmers

The technical learning of the project in terms of programming are the implementation of the vital measurement and creation of a good UI/UX was a continuous process throughout the whole project. One of the aspects that was more difficult and time consuming than expected was the user interface. The project time for completion could have been shorten by using bad UI practices such as having multiple buttons accessing new activities with a big activity stack. However, we decided one of the most important aspects of an App is for the user to easily understand and navigate the App content. This was achieved by having essentially only one activity implemented with ViewPager so the user can easily swipe between tabs that are visible at all times.

Aside from creating a good UI/UX, the other most time consuming aspect of our App was improving the sensors for the vitals measurement. There was multiple tests required to determine which android sensor to use for respiratory rate: Gyroscope vs Accelerometer. As well as calibrating the temperature sensor and testing the image processing for the heart rate monitor for optimal Android camera/flash intensity. The tuning of the signal processing algorithms turns out to be a process that span the entire project to achieve fast and accurate readings.

5 Contribution by Group Members

5.1 Specialist

5.1.1 Chris Stewart

As the specialist in clinical engineering, I was aware of the challenges faced in healthcare and potential ideas for solutions to tackle them. After the initial brainstorming and research into the problem, I was responsible for sharing my knowledge and expertise of clinical practice, physiologic measures and supporting research literature to inform the features and capabilities of the app. During the project, I supported the programmers by researching and recommending sensors such as the TI sensor tag, and gave feedback on the various iterations of the app. I also handled the communication aspect of the project by preparing the initial proposal, spiral and final presentations and this final report as well.

5.2 Programmers

5.2.1 Mu I (Helton) Chen

- Sensor Implementation (Gyroscope, Camera, TI SensorTag CC2650)
- Digital Signal Processing Algorithms (Respiratory, Heart, and Temperature)
- Vital Measurement GUI
- NFC Tag implementation

5.2.2 George Lee

- SQL Database Implementation (Patient List, Vitals Measurements)
- Framework/Structure of App (View Pager/TabHost/Integrating Sensors)
- Graphing/Charting vitals using MPAndroidChart
- Patient ListView and Operations (Export excel file, Name Filter, Share Email)

6 Specialist Context

There are huge implications for patient monitoring as well as the medical device field in general. This app is a proof-of-concept that a mobile device costing only a few hundred-dollars with less than a hundred dollars’ worth of sensors can replicate the capabilities of vitals monitoring medical devices costing thousands of dollars. This could have potential applications for hospital and community care in Canada as well as in developing countries, where the high costs of medical technologies are prohibitive for enabling quality, modern medical care.

An app like this would have significant impacts on nursing workflows, improving speed and reducing workload by automating the measurement and charting aspects of the monitoring vitals task. There would likely be improvements in patient safety and care quality as well. By reducing potential transcription errors and providing computerized recognition of abnormal readings, the risks of missing concerning trends are greatly reduced.

The relatively low cost of the system, coupled with the savings in nursing time will have financial benefits as well – particularly important for the tight budgets of the healthcare system.

7 Future Work

7.1 Potential Future Capabilities

Potential future capabilities that could be added to the app would include: additional sensors such as blood pressure and blood oximetry (for blood O2 saturation) which are critical if the app is to provide a viable, fully-capable alternative to current commercial vitals monitoring systems. Additionally, functionality to allow nurses or physicians to add clinical notes as well as Electronic Medical Record (EMR) integration would be highly useful features.

7.2 Goal Moving Forward

Moving forward we aim to continue work on the app to expand its capabilities and stability. In the short term, we would like to conduct usability testing with nurses and physicians to gather feedback on the prototype, with our goal being to get the app into use in clinics, hospitals and community care centres. We would also like to publish a more refined version either on the Android app store or open source the project so that others may benefit from this work as well.

8 References:

[1] *Hospitalization Rates, Canada, Provinces and Territories*, 1st ed. Alberta: Government of Alberta, 2015.

[2] M. Elliott and A. Coventry, "Critical care: the eight vital signs of patient monitoring", *British Journal of Nursing*, vol. 21, no. 10, pp. 621-625, 2012.

[3] P. G. Rossos, "Electronic health records (EHRs): Where are we going and when will we get there?", University of Toronto, 2015.