# Smart Medication Adherence Phone Case

Section A05, Smart Medication Adherence Phone Case Team
ECE 4012 Senior Design Project

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# Executive Summary

Adherence to medical product has been proved efficient to user's health. However, the problem of a considerable number of patients not following their prescriptions regularly persists. Regarding to the issue, a software-hardware integrated solution utilizing a portable and cost-efficient medical dispensing device, the Smart Medication Adherence Phone Case, is being proposed. The device is a small pill tray integrated as a phone case and attached to the back of an Android smartphone. It can automatically dispense pills via the Bluetooth Low Energy control from the application and record the medical taking behavior back to the smartphone application. Once filled with medical adherence information either by patients themselves or their doctors, the smartphone application will remind the user to take medicines at proper time by sound and vibration notifications. The mechanism in the case is designed to be able to dispense pills piece by piece automatically. The magnetic position sensor senses the pill-dropping accuracy and auto-correct misbehaviors caused by fabrication imperfectness. Linked with medical center and family members, the project will be a great assistant for elder people in case of emergency. With considerations of parts and services being used, the cost of this device would be lowered below $30. The final outcome of this project will be a fully functional prototype of the Smart Medication Adherence Phone Case device integrated with an Android application.

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# Smart Medication Adherence Phone Case

## 1. Introduction

Smart Medication Adherence Phone Case is a convenient and cost-efficient solution that dispenses medications to patients and monitors their medication adherence conditions. The solution consists of a pill-dispensing phone case and an Android application.

### 1.1 <u>Objective</u>

The team prototypes a medication dispensing and monitoring system. Through this system, a patient can retrieve dispensed medications from the pill-dispensing phone case, and refill medications to it upon approval from the Android app. Using the sensors built-in on the Android smartphone, the Android app is biometrically secure and accessible: it requires and recognizes a patient's fingerprint to allow further access. The app enables patients to input the dose and time for his or her medications, set and receive reminders, and monitor individual medication adherence data. The phone case communicates with the Android app via Bluetooth Low Energy (BLE) protocol.

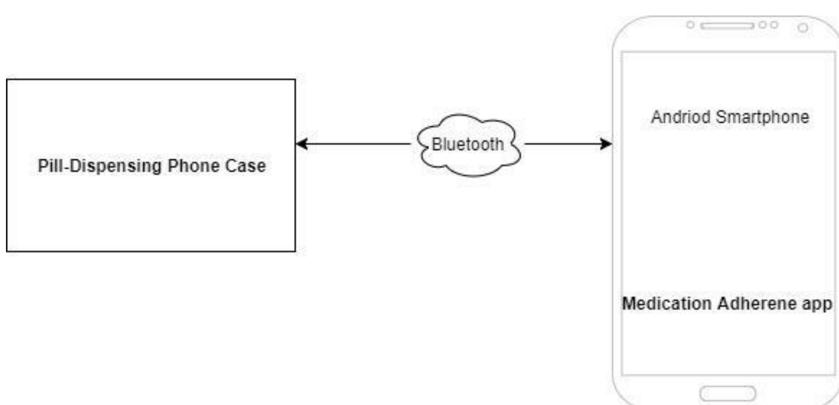


**Figure 1.** System overview block diagram of Smart Medication Adherence Phone Case.

## 1.2 Motivation

Pharmaceutical compliance is a huge medical issue nowadays. Research shows that "between $100 and $300 billion of avoidable annual healthcare costs" attribute to patients to taking their medications on time [1]. The project aims at building a low-cost and portable medication adherence system that separates from other expensive, clumsy and bulky pill-dispensing products on the market. The team decides to take advantage of the popularity of today's smartphones and reuse their built-in sensors. This approach not only significantly reduces the cost, but also trims down the physical size of the pill-dispensing phone case. The final product targets at patients, especially seniors, who need to adhere to their medications on a daily basis with specific types of the pill. The case appears as a convenient add-on gadget to their smartphones. As patients carry their smartphone around, they can still easily adhere to their medications regardless of their physical locations.

## 1.3 <u>Background</u>

Many commercial products that aid patients' medication adherence are already on the market. However, extensive research conducted by the team shows that redundant logging, expensive pricing, and large physical size are usually the drawbacks for the existing products.

***Smart Wireless Pill Bottles***

*AdhereTech* builds a "smart" bottle that senses the amount of medication inside the bottle and updates the value to the cloud server [2]. Furthermore, the OS software API offered by the company leads to an integration of hardware, mobile software and medication platforms. The retail fee is about two dollars each. Another type of pillbox, called *uBox*, is owned by *Abiogenix* [3]. It connects to schedules and calendars stored on user mobile devices. At the beginning of dosing time, it unlocks itself and automatically supplies desired medicine. This feature prevents accidental overdosing. The product does not retail; instead, the company cooperates with insurance company, clinical center and pharmacy to supply a complete solution that covers from the beginning of prescription to the end of recovery. Compared to the proposed solution by the team, *AdhereTech*'s smart pill bottle is as conveniently portable, but there is no mobile application with which a patient can log and track their adherence data.

### *Philips Medication Dispensing Service*

Philips' Medication Dispensing Service is a subscription-based, pill-dispensing machine. It can hold up to 60 cups of medication and dispense medications according to schedule [4]. The overall size of the Philips dispenser is comparable to that of a water boiler. The large size is due to a spinner mechanism inside the dispenser, and a reservoir bank that holds medications not taken on time, preventing overdose. The Dispenser requires connection with a home telephone in order to send out notification to caregivers when patients miss their medications. There is a one-time installation charge of $100 and a monthly $59.95 subscription fee. Compared to the proposed solution by the team, Philips pill-dispenser is immobile and unaffordable. Despite being a complete product, Philips Dispenser is not a viable solution for the majority of patients, such as seniors, who need strict medical adherence.

## 2. Project Description and Goals

The final solution consists of two major components: a Smart Pill-Dispensing Phone Case, and an Android application.

The Pill-Dispensing Phone Case has a dimension similar to an eyeglass case. The exterior portion of the case is laser-cutted with transparent acrylic boards. Inside the container it includes a two-layer design that separates the microcontroller and pill containers. In the upper layer, there are two 3D printed dispensing channels that are also able to hold up tp 20 pills per channel. On the other hand, the bottom layers consist the nRF52 microcontroller board by Adafruit that enables Bluetooth Low Energy communication with smartphone, a rechargeable lithium ion battery power supply and necessary wiring.

The mobile app is developed on the Android platform. The Android app integrates a user-friendly GUI through which patients are notified timely for their medication and their adherence data are recorded.

**General Features**

- Phone Case that dispenses medications and records medication adherence data
- Physical components required to prototype the Phone Case is around $80

**Pill-Dispensing Phone Case**

- Holds and dispenses medications to patients on schedule
- Communicates with Android app by BLE

**Android App**

- Notifies patients to take medications
- Monitors hardware status (battery level, number of pills left etc.)

- Biometrically controlled through fingerprint sensor on smartphone
- Record pill-taking behavior of patients

# 3. Technical Specifications & Verification

## 3.1 **Adafruit Feather nRF52 Bluefruit LE**

**Table 1** contains product specification for Bluetooth Low Energy board with a native-Bluetooth chip, the nRF52832, implemented on the phone case.

**Table 1.** Adafruit Feather nRF52 Bluefruit LE Specification

| **Item** | **Specification** |
|---|---|
| Core | ARM® Cortex®-M4 32-bit processor with FPU, 64 MHz |
| Power | 1.7 V–3.3 V voltage input; up to +4dBm output power |
| Memory | 512 kB flash/64 kB SRAM |
| Transceiver | -96 dBm sensitivity in Bluetooth low energy mode |
| Pinout | 9 GPIO, 8 x 12-bit ADC pins, up to 12 PWM outputs (3 PWM modules with 4 outputs each) |
| Dimension | 2.0" x 0.9" x 0.28" (51mm x 23mm x 8mm) |
| Supporting OS | Android, iOS, Mac OS X, Windows 8+ |

## 3.2 **Dispense Mechanism**

**Table 2** contains design specification for dispense mechanism.

**Table 2.** Dispense Mechanism Specification

| **Item** | **Specification** |
|---|---|
| Storage dimension of output pill | 0.5 cm(l) x 0.5 cm(w) x 1 cm(h) |
| Digital input | 0 or 1 (close or open) |
| Pill dispensing wait time | 5 ± 0.5s |

## 3.3 **Phone Case**

**Table 3** contains design specification for pill dispenser phone case.

**Table 3.** Pill Dispenser Phone Case Specification

| **Item** | **Specification** |
|---|---|
| Input pill maximum | 20 |
| Dimension | Enclosure: 5.836'' (l) x 3.136'' (w) x 1.6536'' (h)<br>Upper compartment height: 0.8156''<br>Lower compartment height: 0.602'' |
| Material | Plexiglass-Acrylic sheet (thickness=3mm; fluorescent yellow) |
| Dispense speed | 5 s/pill |

| | |
|---|---|
| Temperature | 0 ℃ to 50 ℃ |

## 3.4 Samsung Galaxy S6

**Table 4** contains product specification for a target smart phone example.

**Table 4.** Samsung Galaxy S6 Specification [5]

| **Item** | **Specification** |
|---|---|
| Weight | 150g / 5.291 oz |
| Dimension | 146.81 mm x 73.41 mm x 8.64 mm / 5.78" x 2.89" x 0.34" |
| OS | Android 5.0.2 Lollipop with TouchWiz |
| Sensors | Accelerometer, ambient light, barometer, compass, gyroscope, hall, heart rate monitor, HRM, proximity, fingerprint sensor |
| Battery | 3500 mAh |

## 3.5 Android App Specification

**Table 5** contains design specification for smart pill phone case android app interface.

**Table 5.** Android App Specification

| **Item** | **Specification** |
|---|---|
| Function page | 3 |
| Connection type | Bluetooth Low Energy |
| Dimension | Device dependent fullscreen |
| Additional function | Speaker reminder<br>Camera flash light reminder<br>Phone vibration reminder<br>Fingerprint scanner |

# 4. Design Approach and Details

The Smart Medication Adherence Phone Case consists of two major components: hardware including a pill-dispensing mechanism, an embedded microcontroller and a physical case enclosure; software, which is an Android app, provides a User Interface to implement control on the pill dispenser.

## 4.1 Hardware

### 4.1.1 Dispensing Mechanism

The dispensing mechanism of the design consists of two channels that are used to store and dispense pills and two rotation drums driven by motors to transport pills.

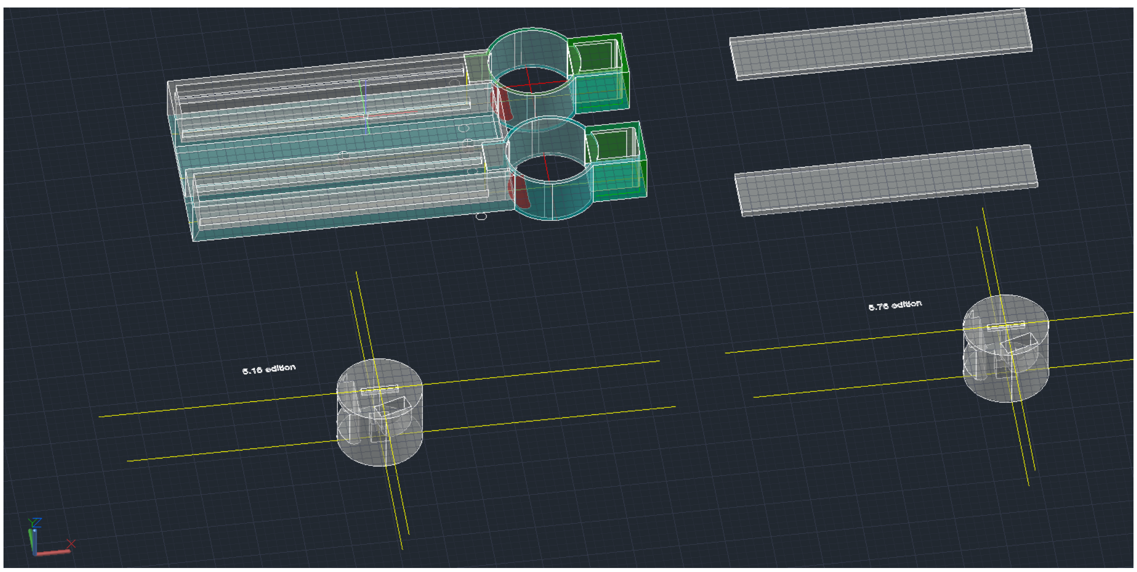

**Figure 2**. CAD design graph showing the dispensing mechanism

The tray can contain 20 normal pills. A rubber band with a pushing stick is used to apply a force pushing the pills towards the rotation drum.

The rotation drum is special-designed with irregular shape so that the pills coming into it will not collide with the other parts of the structure. And the drum will push the following pills back to the tray so that only one pill can enter the drum at a time. After the motor drives the drum and rotate 180 degrees, the pill will be dropped into another tray and then can be fetched out.

### 4.1.2 Microcontroller

The controlling circuitry includes an Adafruit NRF52 BLE microcontroller board, two DC motors with corresponding driving circuits, two hall effect sensors and a 2500mAh 3.3V LiPo battery pack. The DC motors are geared down to fit the rotation speed needed for the drums.

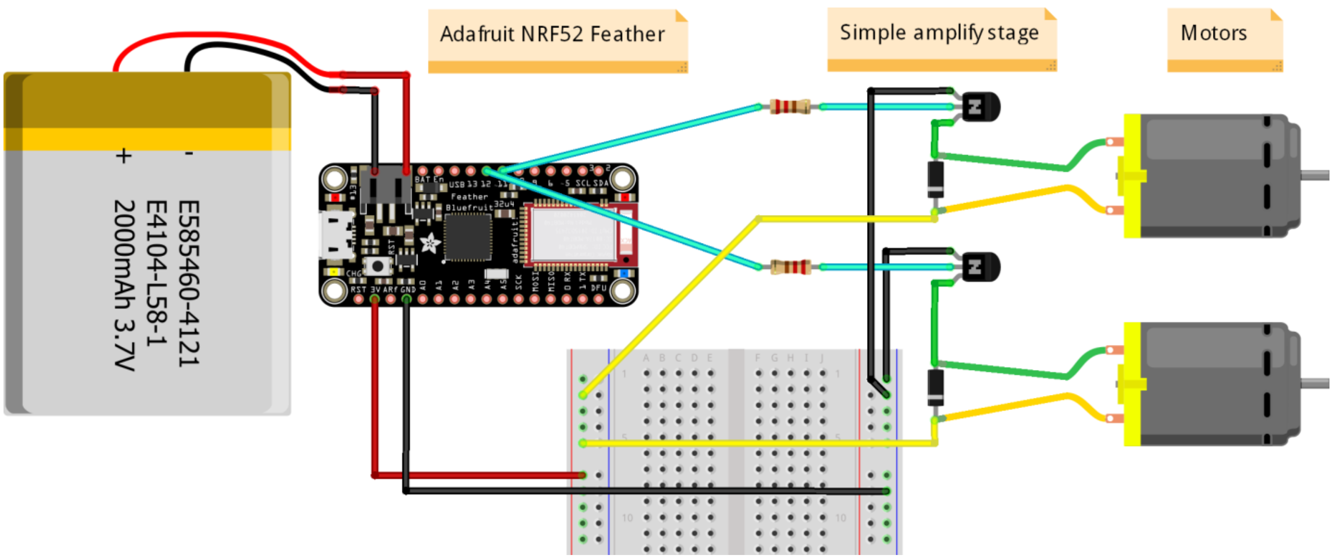


**Figure 3**. System impletation of the controlling circuitry

The driving circuit of the motors are simple BJT-based current amplifiers that amplify the input current of the DC motors.

The microcontroller is programmed in such logic. The BLE board will continuously advertise the BLE signal as peripheral device. Once connected with other Bluetooth controller, it will start recognizing the UART communication sent by the connected device. If some certain characters are received, the motor rotating routine will start running. The hall effect sensors are a simple feedback system to ensure the motor rotates the same degrees every time. A small magnetic is fixed on the drum and the hall effect sensor is placed outside on the cylinder. As soon as the drum rotates to the sensor’s position, the microcontroller will stop the motor from rotating. Thus, although there are some minor delays, the motor can be set to rotate for same degrees every time it rotates.

#### 4.1.3 Enclosure Case

The case enclosure was purposefully designed in 2D in order to quickly prototype. The sketch was drawn and calibrated in AutoDesk's AutoCAD, and the material was then processed via the laser-cutting machine located at the Invention Studio. In this way, it would be very convenient to update our design when change in dimensions, components or design orientations was necessary. A grab latch and a hinge were utilized to form the accessible opening area of the case when patients need to manually reload medications.

### 4.2 **<u>Software</u>**

All user's interactions with Medical Adherence Phone Case will be through the mobile App. The functionality specifically designed for the device is integrated into the previous prototype application, BP-n-ME. After the user or medical provider input the treatment and pill-taking schedule, the App is responsible to send push notifications to notify the user to take medicine at exact times. The app will then transmit the signal through BLE to microcontroller with the users' fingerprint permission to initiate a pill-dispensing action. After receiving the feedback signal from the microcontroller, the App will either record this specific action if it succeeded or report an error if the dispenser fails. A full copy of users' pill-taking behavior will be stored locally in the app. The updated app menu consisting of "Hardware Status" and "Schedule" subpages is shown in figure 2.

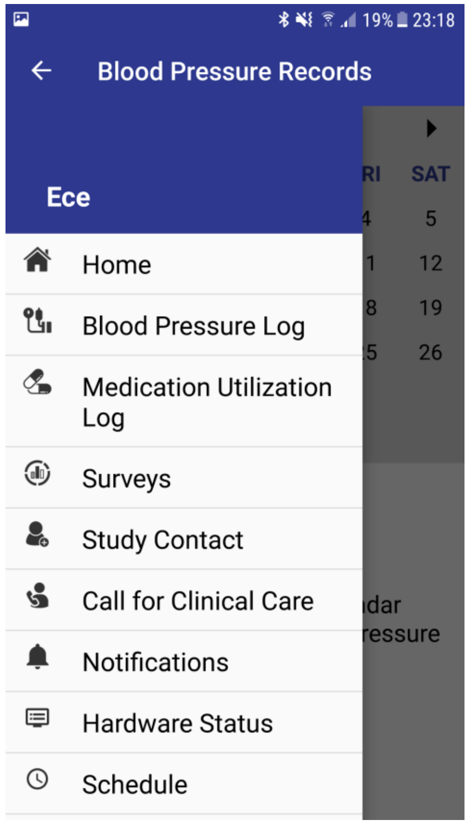


**Figure 4**. App side menu bar

The hardware status page includes everything users need to interact with the hardware. Functions include making new connections to the BLE hardware, disconnect from the hardware, refill pills and dispense pills after fingerprint authorization. The bottom section of the page monitors and modify the hardware connection status. A green text indicates the connection between the app and phone case is established and users can either make new connection or disconnect from the BLE device. In the top section, users are able to choose from drop down menu which medication to reload or dispense while monitoring the number of pills left in the case.   When reloading, the app requires users to manually input the channel number they just reloaded and keep track of the map of medication to channel. Later on, when the dispense button is pressed, the app will dispense the desired medication from correct channel by sending string bytes to the microcontroller after it asks the fingerprint authentication from users.

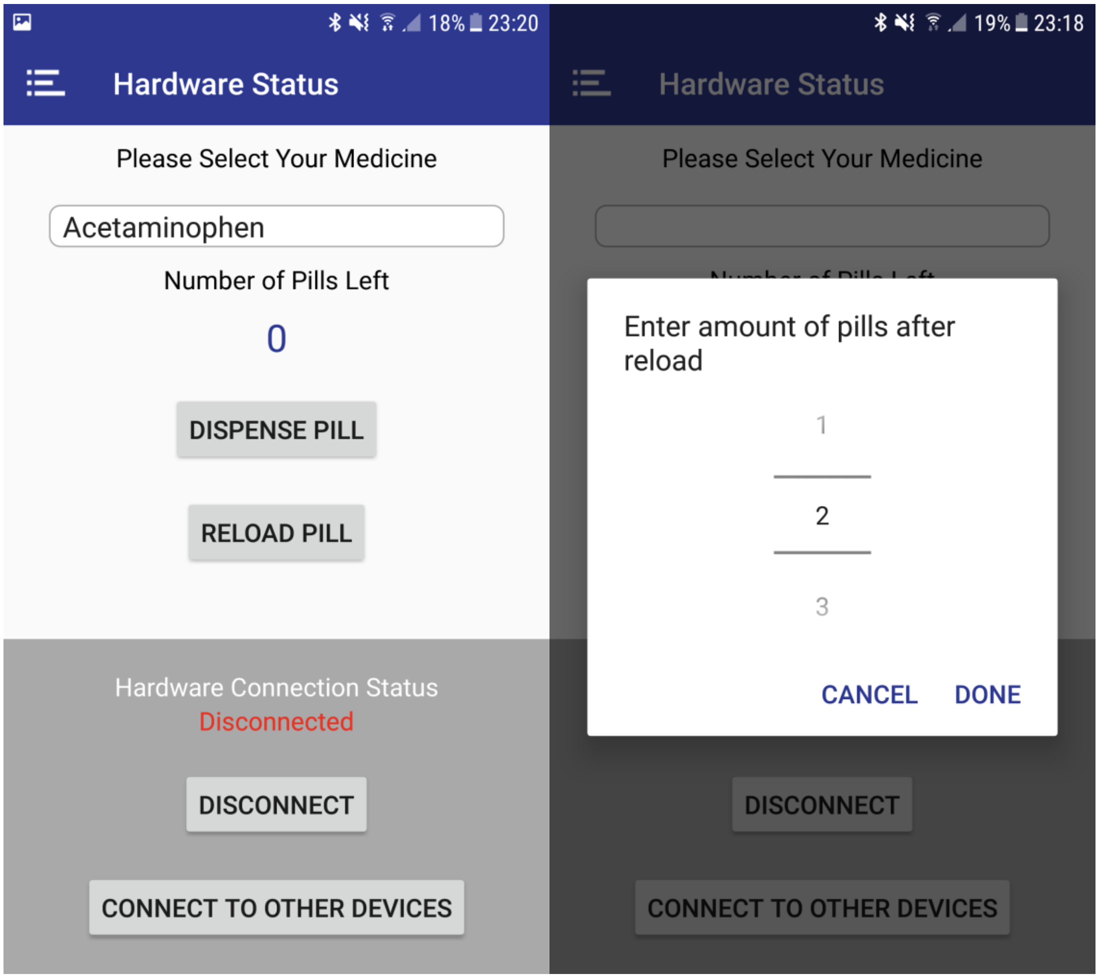


**Figure 5.** Hardware Status Page and Reload Dialog

In the Schedule Page, the user can view his or her pre-existing schedule of the day, including the pill type, the time and the dose. The list is sorted in the timely fashion from the earliest to the latest. The next upcoming pill name and taking time are listed on the top right corner for user's convenience. The pills can be deleted at any time by clicking the trash bin symbol. Then a dialog will prompt to double verify the delete command. Once deleted the list is refreshed and data is taken out from the database storage.

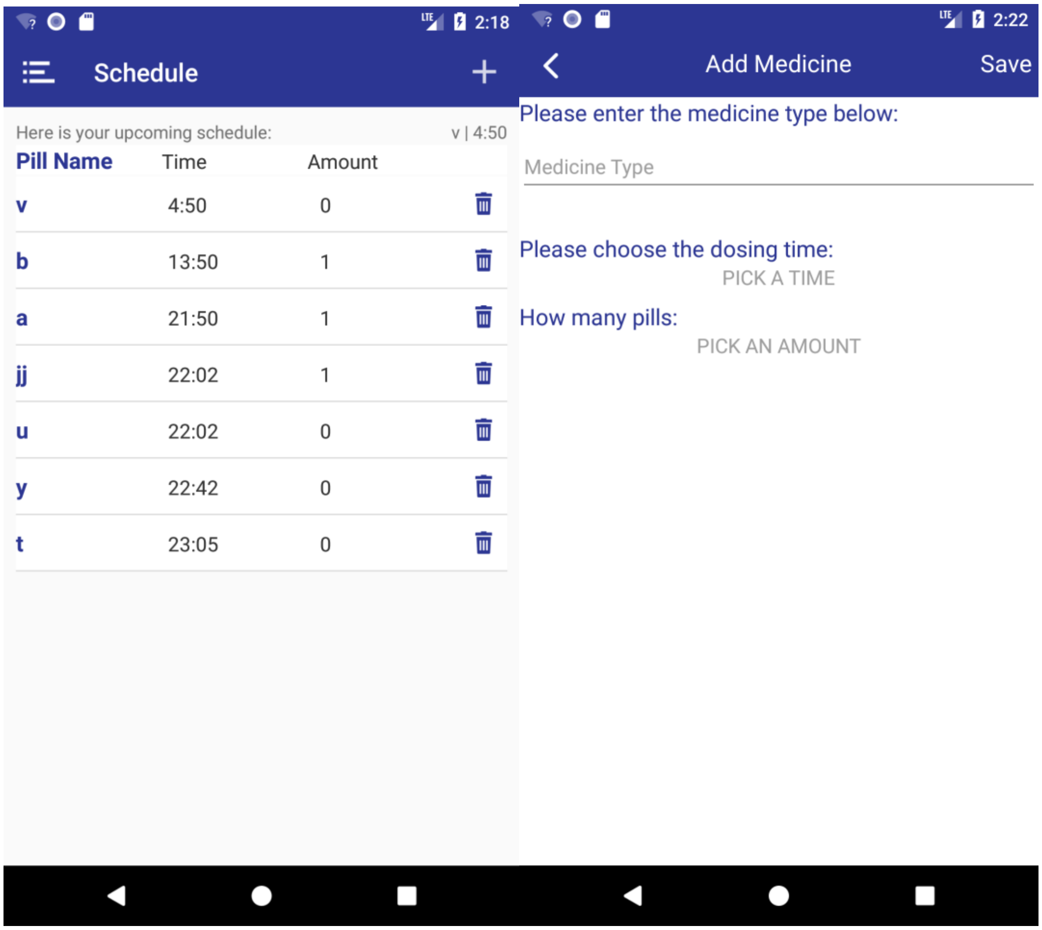


**Figure 6.** Schedule Page and Add Medicine Page

On the top right the "plus" symbol will navigate the app to the "Add Medicine" page. The user can click the "back" to discard the information entered or the "save" to add the pill. The page has three rows asking for user information: the name of the pill, the time of taking the pill and the number of the pill taken. Once clicked either of the two navigation buttons on the top, the app navigates back to the Schedule Page and information is either stored or disregarded depending on user's choice. And the information is synchronized both on the Schedule Page and in the database

### 4.2.1 **Codes and Standards**

The operating system on the prototype Samsung Galaxy S6 is Android Nougat 7.0, and the development software is Android Studio ver 3.0 which supports:

- Java 8 libraries and Java 8 language features,
- Building separate APKs based on language resources,
- Support for Android Test Support Library 1.0 [10].

### 4.2.2 Constraints, Alternatives, and Tradeoffs

An alternative design approach would be developing in the iOS platform. One advantage of developing in the iOS platform is unlike the varying versions of Android system running on different devices, the consistent OS version and hardware device will provide stability and prevent potential bugs caused by app running on different devices. However, the Apple Development SDK cost developers more time and money granting the app access of certain sensors of the device such as fingerprints scanner, recording system and camera access. In addition, certain constraints applied during our decision making such as the target users for the phone case is elders who prefer Android phones over iPhones.

# 5. Schedule, Tasks, and Milestones

The Medical Adherence team will be implement the system in the following four months. The project milestones and the person assignments as well as the approximate difficulties are being listed in Appendix A. Appendix B contains the GANTT chart displaying the tasks and time management.

# 6. Final Project Demonstration

For our project, the goal was to successfully simulate the full procedure. In the ideal scenario, such procedure includes:

1. A vibration notification from the “BP-n-ME” app, alerting the patient to take his or her pre-assigned portion of medication;
2. Fingerprint identity check;
3. Successful dispensing of the pre-assigned number of medications from the phone case;
4. Logging of the pill-taking event the “Medication Utilization Log” on the app.

The entire demonstration procedure took place at the Capstone Expo. Dr. Maysam Ghovanloo was present at the Expo and team members performed the Demo on site.

However, due to the partial success of several features of our hardware/software, simplifications were made to the above-mentioned procedure to ensure initial success in the Demo process. In other words, the currently working procedures of pill-dispensing involves a degree of confinement.

- When installed on new Android devices, The “BP-n-ME”app could sometimes incur crashes when trying to access “Medication Utilization Log” and “Hardware Status” features. As a temporary work-around for the Demo, terminating and restarting the app solved the issue;

- Pills tend to be stuck inside the dispensing cylinder when not oriented vertically. As will be mentioned in Conclusion, this happens due to a combination of the imperfect approach to the design of the dispensing mechanism and inappropriate selection of parts (DC motor is too weak to be powered to spin when a stronger force from rubber band is applied). To address this problem at the Demo, we decided to always orient the case vertically in demonstration (thereof using gravity to dispense pills), disable the rubber band and slow down the DC motor to make spinning more accurate.

The photos of the completed product are listed in the appendix.

The video link to our group's Capstone Expo Final Demonstration can be found here on our website: https://www.youtube.com/watch?v=iQPyAJJPPk4

# 7. Marketing and Cost Analysis

## 7.1 Marketing Analysis

Currently several products exist in the market, sharing the same goal of increasing medical adherence as the proposed solution. However, the features of the existing products and the technology used behind them are different from the solution. *Vitality* has made a *GlowCap* that will glow to remind the patient when it is time for patient to take medication [11], but it doesn't specify the amount of medication to take and therefore the patients may make mistakes. Another product is the automated medication dispensing service provided by *Philips* [12], which dispenses the required amount of medication and remind the patient to take them. However, the dispenser is large and therefore is not convenient to carry when the patient is on vacation. The smart medication adherence phone case utilized the sensors build on the smartphone and therefore is smaller in size and cheaper in cost. Thus, the smart medication adherence phone case is unique in the market.

## 7.2 Cost Analysis

The smart medical adherence phone case is composed mainly of a phone case, the dispensing mechanism inside the case, an Adafruit Feather nRF52 Bluefruit LE microcontroller and an Android App that is used to control. The smartphone doesn't come with the case and therefore is not counted as a cost. The following table shows a breakdown of the cost of the parts used to make the prototype.

| Item name | Cost | Number | Total Cost |
|---|---|---|---|

| | | | |
|---|---|---|---|
| nRF52 | $25 | 1 | $25 |
| Pill dispenser case | $30 | 1 | $30 |
| Power Supply, cable and packaging | $30 | 1 | $30 |
| Total Cost | | | $85 |

**Table 6**. Component costs for prototype.

The development cost is shown in the following table. The labor cost is assumed to be 30 dollars per hour. The development of the Android App and the experimentation of pill dispensing mechanism is expected to take most of time since their complexity.

| Project Component | Labour Hour | Labour Cost | Part Cost | Total Component Cost |
|---|---|---|---|---|
| Dispensing Mechanism Design | 10 | $300 | $60 | $360 |
| Dispensing Mechanism Testing | 40 | $1200 | 0 | $1200 |
| Android App Development | 50 | $1500 | 0 | $1500 |

| | | | | |
|---|---|---|---|---|
| Integration and Testing of All Parts | 20 | $600 | $20 | $620 |
| Reports | 10 | $300 | 0 | $300 |
| Weekly Meeting | 200 | $6000 | 0 | $6000 |
| Demo Prep | 10 | $300 | 0 | $300 |
| Total Cost | | | | $10280 |

**Table 7.** Development Costs.

The fringe benefit is 30% and overhead is 120%. Therefore, the total development cost is $29348, as shown in the table 8.

| | |
|---|---|
| Parts | $85 |
| Labor | $10200 |
| Fringe Benefits, % of Labor | $3060 |
| Subtotal | $13340 |

| | |
|---|---|
| Overhead, % of Matl, Labor & Fringe | $16008 |
| Total | $29348 |

**Table 8**. Total Development Costs.

The production will consist of 5000 units sold over a 5-year period at a price of $100. Table 4 shows the expected profit and selling price calculation of each product. The sales expense will be 5% of the selling price, which is $12.5. At the price of $250 per unit, the total expected revenue of 5000 units is $1250000, which yields a profit of $38 per unit. The labor cost of assembly and testing is $20 per hour.

| Based on | 5000 Units |
|---|---|
| Parts Cost | $85 |
| Assembly Labor | $4 |
| Testing Labor | $2 |
| Fringe Benefits, % of Labor | $1.8 |
| Subtotal | $87.8 |
| Overhead, % of Matl, Labor & Fringe | $105.36 |

| | |
|---|---|
| Total | $193.16 |
| Sales Expenses | $12.5 |
| Amortized Development Costs | $6 |
| Subtotal, All Costs | $211.66 |
| Profits | $38 |
| Selling Price | $250 |

**Table 9**. Selling Price per Unit Determination.

# 8. Conclusion

Currently the pill tray is 60% functional. The smartphone app behaves as expected most of the times, except for some minor bugs when adding pills. However, the hardware components have several issues. First, the approach to the dispensing mechanism is not robust enough. Using pill channels to store pills and depends heavily on the accuracy of the 3D-Printing. A small scratch or bump in the channel or the rotating drum will cause unexpected collision among pills. Secondly, we planned to have a force pushing the pills into the rotating drum. But since our motors have low power consumption, they often fail to rotate when the force is high. The rubber band solution cannot provide a manageable force to push the pills without disabling the motors. Currently we need to make use of the gravity by placing the product upwards. In this case a pill-dispensing success rate of 80% can be reached. For future improvements, the dispensing mechanism might need some redesigning to have a more robust performance. The system voltage can be raised to 5V or higher so that the motors can be replaced by stronger ones with higher rating. Thirdly, the hall effect sensors burned out on the demo, so the motor can only be controlled by rotation time and voltage, which is not accurate enough for continuous pill dispensing.

The size of the phone case (measured as 5.836’’x 3.136’’x 1.6536’’), which is not small enough to fit into a regular-sized pocket, also provides space for future minor adjustment. One may replace the currently used gear combination in the motor with a smaller one to reduce the size of the design. Moreover, the capacity of the battery being used is beyond the power requirement of the design. Therefore, a smaller battery can be used to further reduce space.

Looking back to our product, the mechanical design took us a large portion of time, but the result is still not as expected. If we could spend more time research on the dispensing mechanism, we should have more preparation over the potential obstacles we are facing. Besides, starting the building-testingmodifying cycle early is another important point when doing such team project. If we have more time, we will improve our dispensing mechanism and the motor control. But since we did not start actual testing early, we had to rush through the testing and improving steps and eventually impact the quality of our product.

During the design expo, the product received a considerably amount of acclaims over the idea of carriable pill tray and the combination of the smartphone and the pill tray case. To improve the overall quality and make it more applicable to market, as stated before, the overall size need to be further reduced by choosing smaller motors and batteries. The dispensing mechanism also need structural enhancement to satisfy the robustness requirement. Moreover, the motors can be upgraded with more complex feedback systems such as rotary encoders or even use the servo motors instead of the DC motors.

# 9. Leadership Roles

All the tasks assigned to each member are attached in the appendix.

For the team leadership roles, Xiannan Di is the Group Leader that leads all meetings and design progress throughout the semester. Kedeng Pan is the Webmaster that drafts and updates the website for senior design project. Xingyuan Zhu is the Documentation and Parts Coordinator that records project related profiles and organizes the project parts. Yuhao Lin is the Expo Coordinator and is therefore in charge of expo demonstration details. Zhipeng Shao is the Email Manager that drafts weekly email report.

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# Appendix A

## Project Milestones Table

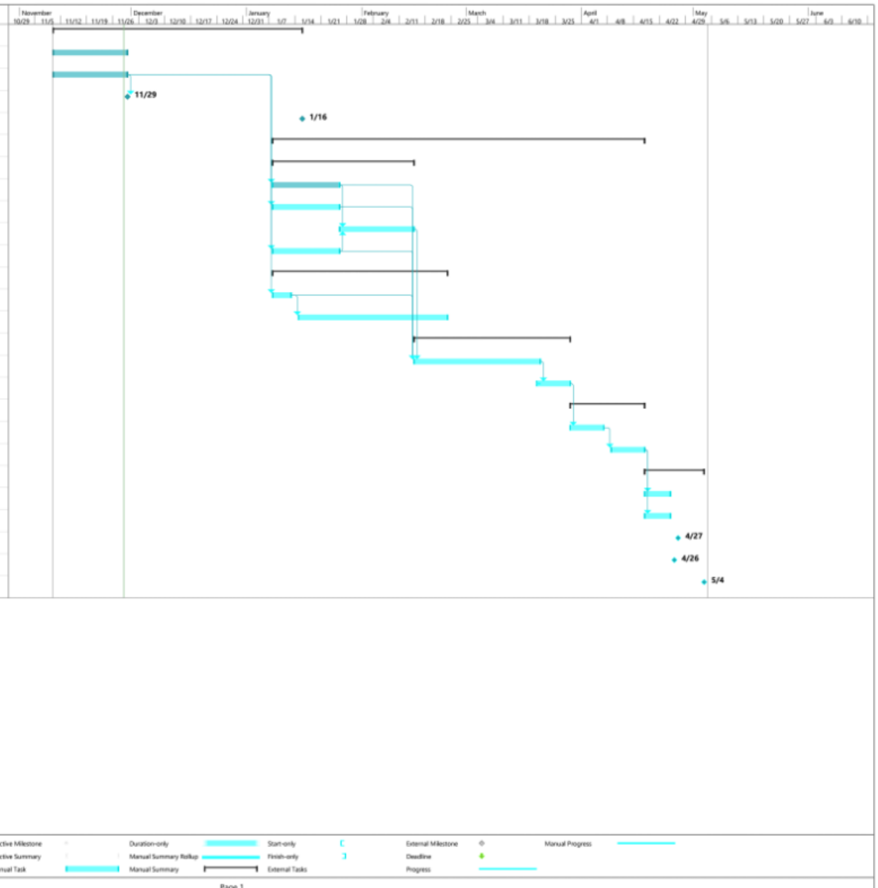
Risk levels are evaluated by relevant previous background or experience. High risk level means no previous experience is presented.

| **Task Content** | **Member Assignment** | **Risk Level** |
|---|---|---|
| Planning, Preparation and Deliverables | | |
| Order Parts | All | Low |
| Project Proposal and Summary | All | Medium |
| Proposal Presentation | All | Low |
| Progress Report | All | Low |
| Final Demonstration and Presentation | All | Medium |
| Final Report | All | High |
| Pill Tray Case Design | | |
| Dispensing Mechanism and 3D Printing | All | High |
| Microcontroller Control and Power Distribution | Zhu, Lin | Medium |
| Case Design | Lin, Zhu | Medium |
| Smartphone App Development | | |
| Bluetooth Communication and Hardware Status | Pan | High |
| UI Design | Pan, Di | Medium |
| App Function | Di | High |
| App and Device Communication | | |
| Bluetooth Communication | Lin, Pan, Di | Medium |
| Inspection and Improvement | All | Low |

# Appendix B

## GHANTT Chart

| ID | Task Mode | Task Name | Duration | Start | Finish |
|---|---|---|---|---|---|
| 1 | | **Preparation and Proposal** | **47 days** | **Fri 11/10/17** | **Tue 1/16/18** |
| 2 | | Purchase Microcontroller and Sensors | 14 days | Fri 11/10/17 | Wed 11/29/17 |
| 3 | | Project Proposal | 14 days | Fri 11/10/17 | Wed 11/29/17 |
| 4 | | Project Proposal and Project Summary Form Due | 0 days | Wed 11/29/17 | Wed 11/29/17 |
| 5 | | Oral Project Proposal Presentation | 0 days | Tue 1/16/18 | Tue 1/16/18 |
| 6 | | **Design and Implementation** | **72 days** | **Mon 1/8/18** | **Tue 4/17/18** |
| 7 | | **Mbed Prototype** | **28 days** | **Mon 1/8/18** | **Wed 2/14/18** |
| 8 | | Pill Tray Case Dispensing System | 14 days | Mon 1/8/18 | Thu 1/25/18 |
| 9 | | Microcontroller and Power | 14 days | Mon 1/8/18 | Thu 1/25/18 |
| 10 | | Pill Tray Case Design | 14 days | Fri 1/26/18 | Wed 2/14/18 |
| 11 | | Potentail PCB Design | 14 days | Mon 1/8/18 | Thu 1/25/18 |
| 12 | | **Smartphone App Development** | **35 days** | **Mon 1/8/18** | **Fri 2/23/18** |
| 13 | | App Function Brainstorm and Design | 5 days | Mon 1/8/18 | Fri 1/12/18 |
| 14 | | App Programming | 30 days | Mon 1/15/18 | Fri 2/23/18 |
| 15 | | **Device and Smartphone Communication** | **30 days** | **Thu 2/15/18** | **Wed 3/28/18** |
| 16 | | Bluetooth Implementation | 24 days | Thu 2/15/18 | Tue 3/20/18 |
| 17 | | Device Testing and Debugging | 7 days | Tue 3/20/18 | Wed 3/28/18 |
| 18 | | **Project Inspection and Improvement** | **14 days** | **Thu 3/29/18** | **Tue 4/17/18** |
| 19 | | Survey and Feedback | 7 days | Thu 3/29/18 | Fri 4/6/18 |
| 20 | | Implement Potential Improvement | 7 days | Mon 4/9/18 | Tue 4/17/18 |
| 21 | | **Deliverable** | **12 days** | **Wed 4/18/18** | **Fri 5/4/18** |
| 22 | | Project Summary and Documentation | 5 days | Wed 4/18/18 | Tue 4/24/18 |
| 23 | | Presentation Preparation | 5 days | Wed 4/18/18 | Tue 4/24/18 |
| 24 | | Design Expo and Final Presentation | 0 days | Fri 4/27/18 | Fri 4/27/18 |
| 25 | | Project Demonstration | 0 days | Thu 4/26/18 | Thu 4/26/18 |
| 26 | | Project Report and Summary | 0 days | Fri 5/4/18 | Fri 5/4/18 |



# Appendix C

Product Photos

Can be found in the provided link:

http://ece4012y2018.ece.gatech.edu/spring/sd18sGM1/


SAMSUNG
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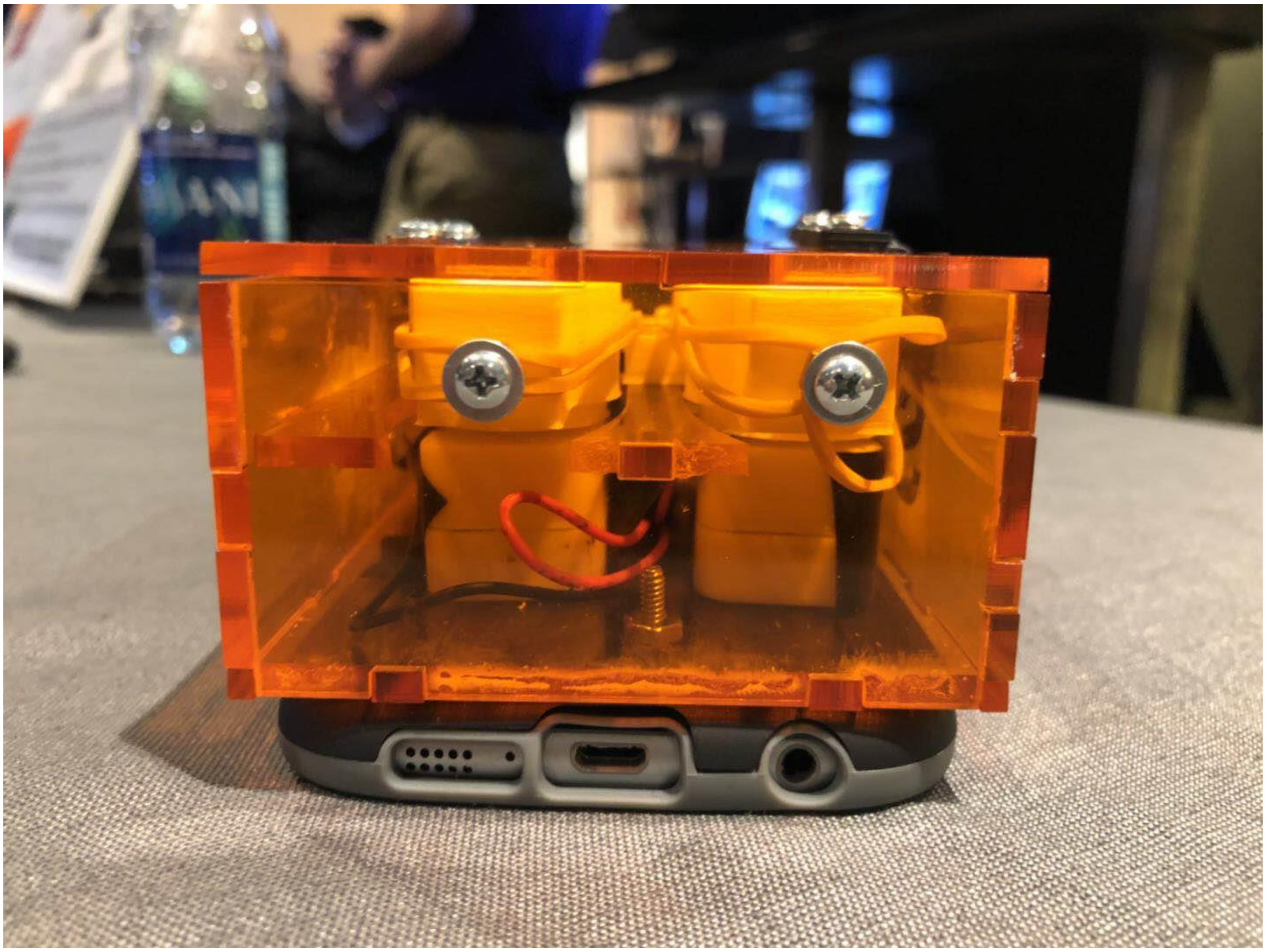

## Appendix D

App and microcontroller codes, CAD files can be found on the website

http://ece4012y2018.ece.gatech.edu/spring/sd18sGM1/