Design of a Device to Help Severely Mentally Ill Patients Quit Smoking

Final Report

BME 200/300

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Acknowledgements

Abstract

We propose a design for a system, called the Pack Pal, to help severely mentally ill patients quit smoking. The proposed system consists of a cigarette case and a smartphone application. The case is equipped with multiple infrared LED sensors   and a linear actuator locking mechanism. A button will indicate an opening attempt and the sensors will detect the number of cigarettes removed. Upon being accessed the   case interacts with the smartphone wirelessly via Bluetooth (v4.0), sending ASCII characters corresponding to sensor activation. Each time the user accesses the case; the smartphone application will take the data sent from the case and format it appropriately.

A copy of the formatted data will be reported weekly to the patient's healthcare professional. Data will also be available through the smartphone application in an easily accessible and understandable manner for the users so that they can monitor their progress throughout the quitting process. Overtime, the users will gain knowledge about their smoking habits and will be able to hold themselves accountable for their cigarette use. They will practice distraction techniques (e.g., playing a video game, listening to music or engaging in another related activity), to deter them from smoking.

Problem Statement

      The objective of this project is to design a case for holding cigarettes that is augmented to specifically help people with severe mentally illness (SMI) quit smoking. The case is called "Pack Pal". It will house three sensors. The first sensor is used to detect if the user attempts to open the case. The second sensor will determine whether the case has already been opened. The third sensor is used to find out how many cigarettes are removed from the case. The data from access attempts will be continuously transmitted to a smartphone wirelessly. This is done via bluetooth (v4.0) as serial characters code for various responses to sensors. For example, character 'a', would represent access to the case. In this way, the smartphone will detect the access attempts, opening and closing of Pack Pal. Each time the user accesses the case, the phone application will ask the user a series of questions about his/her desire to smoke, the environemental or emotional cue that prompted the urge, and to rate the salience of the urge. Overtime, the users will gain knowledge about their own use and will then be able to use skills (aquired via the application) to cope with not having a cigarette. One of these skills could be to do something else (e.g., playing a video game, listening to music or doing another activity that the participants have indicated helps them avoid smoking), or to remind them of the reasons that they want to quit (e.g., the access attempts, opening and closing of Pack Pal, and displaying a picture of their child, pet or loved one). In addition, the application will send daily updates to the subject and/or to any clinician or provider the subject specifies.

1.0 Introduction

1.1 Background

Our client for this project is Dr. David Gustafson, an emeritus research professor of Industrial and Systems Engineering, director of the Center for Health Enhancement Systems Studies at the University of Wisconsin-Madison and his colleagues from Dartmouth College, Dr. Mary Brunnette (MD), an Associate professor of psychiatry, and Dr. Joelle Ferron, an Assistant professor of psychiatry.

A major issue with mental health patients that is often improperly acknowledged is tobacco and/or drug addiction. The rate of cigarette smoking is much higher among people with severe mental illnesses than that of the general populace [3]; 45%–90% in the severely mentally ill (SMI) as opposed to only 20% in the general populace [2]. According to Dr. Ferron "approximately three-quarters of people with severe mental illnesses smoke cigarettes" [3]. Bridget Grant from the National Institutes of Health conducted a study to view the correlation between SMI (defined as DSM-IV Axis I and II disorders) and nicotine addiction. In an assessment of 43,093 subjects through face-to-face interviews, Grant determined that individuals with comorbid addiction and mental illness consume a large percentage of the total cigarettes consumed by the smoking population [5]. This statistics shows that cigarette addiction is not only more prevalent in the SMI but it is also a more serious problem in this group.

Individuals who are addicted to nicotine and suffer from SMI have more severe addiction. Individuals with SMI inhale more deeply per puff causing particularly harmful effects [3]. The cumulative effects of this severe smoking behavior cause death 25 years earlier in individuals with SMI (versus 14 years earlier in smokers in the general population) mostly due to cardiovascular diseases (generally caused by smoking) [4]. Individuals with Schizophrenia, a well studied SMI, have particular difficulty managing smoking. In fact, about 75% of people with schizophrenia smoke cigarettes.

Schizophrenia will be particularly focused on in this project because of the depth of research on this disease and because of the high overlap with nicotine addition. Schizophrenia is a major psychiatric disorder characterized by several breakdowns in normal brain function. These breakdowns are classified into positive and negative symptoms. Positive symptoms refer to symptoms that are not often experienced by persons without Schizophrenia. Positive symptoms include hallucinations both auditory and visual (though not very common), delusions and distinctive disorderly actions. Typical negative symptoms (those symptoms that are deficits of normal function) include lack of emotion, poverty of speech, lack of desire to form relations and inability to experience pleasure. Cognitive deficits are particularly distinctive of Schizophrenia these include disorganized speech and grossly disorganized behavior.

Smoking cigarettes is extremely harmful and causes 87 %of lung cancer deaths, and causes other forms of cancers and health problems, including lung disease, heart and blood vessel disease, stroke and cataracts (8). Higher rates of smoking in mentally ill people lead to particularly high rates of diseases caused by smoking, resulting in shorter life expectancy in this population (8). There is little doubt that smoking has many adverse impacts on one's health and that this problem is particularly prevalent in mentally ill people.

Quitting smoking is very difficult due to the strong psychological and physical additions this habit creates. In the population of smokers who do not quit, nearly half will die of smoking-related problems. After quitting smoking, circulation begins to improve, and blood pressure starts to return to a normal, lower state. Short-term problems such as anxiety or irritability can occur when one tries to quit smoking (8). It is common for smokers to attempt to quit more than once and often to seek aid in the form of professional counseling and quitting programs because of the level of addiction smoking creates. The difficulty of quitting can be exacerbated by mentally illness.

Meanwhile, Dr. Ferron conducted an 11-year study in which followed 174 individuals with Schizophrenia and co-occurring substance abuse issues. 89% were smokers at the initiation of the study and 11 years later only 17% were not smoking. It is interesting to note that the sample did not use evidence proved methods to help quit including nicotine replacement and bupropion (3). This suggests that these treatments are inaccessible or unwelcome to the SMI (at least in individuals with co-occurring substance abuse problems).

Since smokers with severe mental illnesses often do not use traditional additional resources (to quit smoking), additional help and guidance may be necessary to aid these patients in quitting process. It has been determined that this disconnect between SMI smokers and traditional quit smoking resources is due to lack of interest (6,7), an inability to access resources (9) or other unknown reasons. Research shows that a tailored program for the mentally ill (designed and tested with the needs of the SMI in mind) struggling with addiction can improve the odds for individuals trying to quit (1,2).

In order to develop additional quitting resources, one needs to understand which resources are not used and why. Dr. Brunette also conducted survey of websites dedicated to providing help quitting smoking (1). A team of five experts measured the usefulness (based on content) and usability of the first four hits from a Google search for quitting smoking. These sites were then presented to 16 SMI smokers who were observed and interviewed on the experience. A website that was navigable by the subjects was rated as lacking in content by the experts. One site that was rated highly by the experts in both categories was inaccessible to the subjects because they could not navigate the site to find information the experts had deemed essential in quit attempts. These results demonstrate that the SMI smokers may not take advantage of quitting resources because they cannot access

them. In addition, it shows that what may seem accessible to experts is not necessarily accessible for the SMI smokers.

The prevalence of smoking in SMI smokers in conjunction with the inaccessibility of resources to this population calls for a more tailored quitting system. This system should be built from the results of the previous studies; e.g., Dr. Brunette's computer cessation aid. The system would be designed with information about how SMI individuals interpret information and be targeted toward reaching this under supported audience. The final goal would be to have a comprehensive program that assists SMI smokers in quitting ideally through constant (24 hours a day) monitoring and accessible information. A large gap in the research on this topic is why SMI people, in particular, turn to smoking and often develop addictions more than other members of the general populace. Several studies found that SMI people can use structured computer programs to aid in quitting process (4). Additional research should be done to evaluate the usefulness of this type of additional treatment specific to the SMI smokers to help with quit smoking.

1.2 Motivation

Research shows that SMI patients are willing to quit smoking. There are many useful quitting programs available for the general population, but there are no programs designed specifically for SMI patients. The Pack Pal acts as a coach for the user and also collects important data that aids the user in reaching their goals. A trip to Chicago is planned in order to interact with SMI patients to gain a better understanding of how to tailor the Pack Pal to their needs.

2.0 Design Specifications

2.1 Case Requirements

The case needs to stay locked until the user attempts to open it, wherein the case will stay locked for a specific time interval before opening. The case also needs to sense three pieces of data: when the case is attempted to open, when the case actually opens, and the number of cigarettes that are removed from the case. Finally, the case is required to wirelessly transmit the data to the smartphone.

2.2 Smartphone Requirements

The smartphone needs to analyze the data from the case. When the user attempts to smoke a cigarette, the smartphone needs to display countermeasures to discourage the smoking behavior. The phone could display a picture of a diseased lung, call family or friends for a distraction, or use social media for support. The phone will also record what triggered the urge to smoke and will rate the craving

of the cigarette. The users will also be able to access weekly updates on how many cigarettes they have smoked that week to compare with other weeks.

3.0 Design Options and Alternatives

In order to meet the product design specifications, many design options were brainstormed and considered. Each aspect of the project had multiple routes for implementation, and each option had to be carefully analyzed. For the case, there were three main design aspects: sensing the presence of a cigarette, battery/power and the locking mechanism.

3.1 Cigarette Sensing

Accuracy and consistency of measurements in the cigarette sensing system are the two important factors that should be considered in the brainstorming process. It is necessary to have an accurate reading every time the cigarettes are checked and to have this reading be consistent between checking periods. Another issue is the size of the electronic circuitry and its power supply. In fact, the overall sensing system should be small enough to be conveniently housed into the final case. Therefore, the power consumption of the system needs to be carefully evaluated in order to select the smallest possible battery. Also, attempts should be made to minimize the number of components required to implement the electronic circuit.

3.1.1 Separate IR LED and IR Sensor

The first design option refers to a system that is dependent on an array of IR LEDs and corresponding sensors. The system works under the principle of IR transmission. A schematic diagram of the cigarette handling in this system is shown in Fig. 1. As can be seen in this figure, when a cigarette is present in the case, the IR LED light is blocked and the sensor will not pick up a signal. However, when the cigarette is removed, the IR signal will no longer be blocked and will be picked up by the sensor that, in turn, will send a signal to the microcontroller indicating the absence of a cigarette.
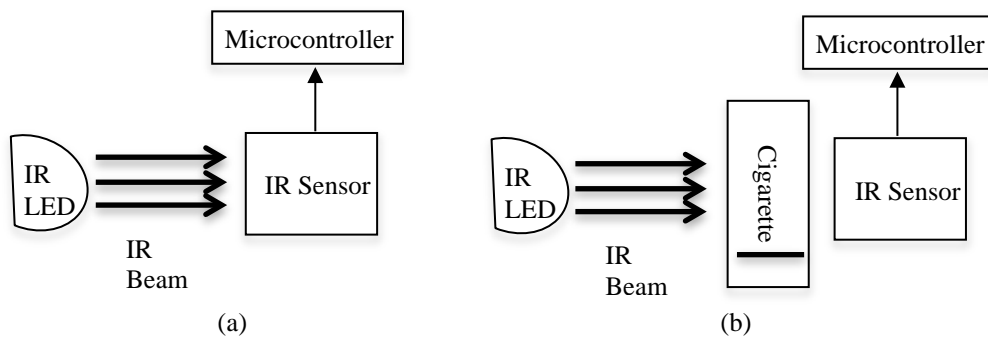

Figure 1. Cigarette handling in the separate IR LED and IR Sensor design; (a) without cigarette and (b) with cigarette.

3.1.2 Integrated IR LED and IR Sensor

In the second design option, the IR LED and IR sensor are integrated together, forming a single detection system. The-system works under the principles of IR reflection and absorption. A schematic diagram of the cigarette handling in this system is shown in Fig. 2. As can be seen in this figure, each cigarette will have an accompanying sensor and LED. In the presence of a cigarette, the LED will transmit a light beam that reflects off of the cigarette, radiating back to the sensor where it can be read. Upon the removal of a cigarette, the LED will transmit an IR signal that is not reflected back to the sensor, indicating the absence of a cigarette.
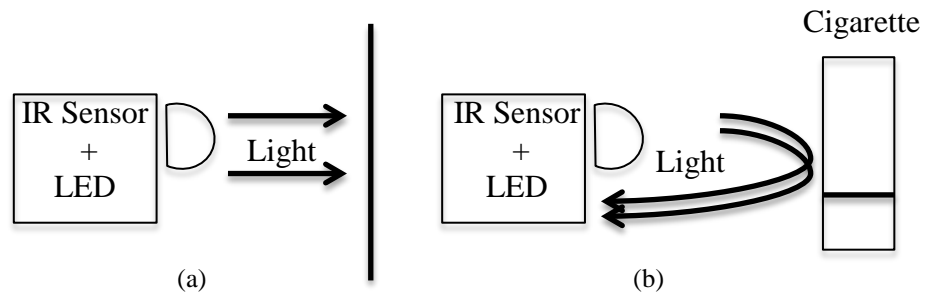
Figure 2. Cigarette handling in the integrated IR LED and IR sensor design; (a) without cigarette and (b) with cigarette.

3.1.3 Flex/Strain-sensitive resistor

The third design option is based on the use of a flex or strain-sensitive resistor. In this design, associated with each cigarette there will be a flex resistor. A typical flex resistor consists of a long, thin conductive strip such that a small amount of stress results in a strain over the effective length of the conductor, which in turn, changes its resistance. When a cigarette is placed in the case, it will exert a small amount of stress on the resistor. The resultant strain over the length of the resistor would cause a change in its resistance, which could be amplified and measured by the microcontroller. When the cigarette is removed, the strain on the resistor would be decreased, resulting in a decrease in its resistance. The-change of resistance would again be amplified and read in the absence of a cigarette.

3.2 Battery/Power

Since Pack Pal is a portable electronic device, it will need to be battery powered. Reliability of the battery or batteries is very important for this device as well as the overall efficiency of the system. The battery unit should be cost effective to keep the price per unit at a minimum. Also, it is important to consider the cost imposed on the end user while brainstorming and comparing

designs. Lastly, limiting the physical size of the battery unit is the key to fitting the whole system into a smaller space.

3.2.1 Replaceable Batteries

A power unit utilizing replaceable batteries is a simple design. It is cost effective for the development phase and prototyping; however, it is more expensive for the end user.

3.2.2 Removable Lithium-Ion Battery

The second design option considered was a lithium ion battery with an external charger. In this design, the battery would be removed each time the case needed to be charged. It is more expensive for the development phase and prototyping, but would save money for the end user.

3.2.3 Wall Charge Lithium-Ion Battery

In the third design option, a semi-permanent lithium-ion battery is utilized. In this option, the battery would always be in the case, only to be accessed if there is an error or the battery has greatly declined in charging performance. A wall-charger could then plug into the case and charge the battery much like a modern day cell phone.

3.3 Case Locking Mechanism

While brainstorming design options for the case locking mechanism, the size of the locking system was one of the key factors to be considered. Again, this aspect of the design is important because the final design will have to be placed inside a cigarette case. Also, the physical strength of the lock was a major factor; the case should not be opened forcefully by the patient while in the locked state. Reliability of the locking mechanism was taken into account during the brainstorming process because the user should depend on the lock being locked when it is supposed to be, but more importantly, on unlocking when triggered. Lastly, the amount of power consumed by the locking system at rest (locked) and active (unlocked) was important in the brainstorming process.

3.3.1 Magnetic

The first design option would include a permanent magnet positioned opposite of a wire coil. When an electric current flows through the coil, a magnetic field oriented opposite to the permanent magnet would develop, holding the case closed through magnetic attraction. When the current flow is interrupted, the case would unlock.

3.3.2 Linear Actuator

The second design option would be a custom linear actuator. This design would consist of two small loops positioned on opposite sides of the case. While closed, the two loops would overlap and a small metal rod would slide between them, locking the case. On one end of the rod there would be a magnet surrounded by a wire coil. At rest, the rod would be extended and the case would be locked. When an electric current is applied to the coil, a magnetic field opposite of the magnet on the rod would be created, withdrawing the rod from the loops and allowing the case to be opened.

4.0 Design Matrices

In each design matrix, the design traits were given different weights based on overall importance to the design. Each design option was then analyzed and given a score between one and ten for each trait. That value was then multiplied by the weight and then all of the scores were summed to produce the cumulative score. The design option with the highest score for each category was chosen as the design to pursue.

4.1 Cigarette Sensing System

In the evaluation of the design matrix for various cigarette-sensing systems, the reliability of the system in each case was considered to be the most important aspect of the design. The power consumption of the electronic circuitry was given the next highest weight due to its very important role in each design. Finally, the number of components and the ease of implementation were considered moderate factors. Results of the design matrix for various cigarette-sensing systems are summarized in Table I. From the results shown in Table I, it is concluded that the "integrated IR LED/sensor" design gained the highest score.

Table I. Design matrix for various cigarette-sensing systems

Design Factor (Weight)	Design Type		
	Separate IR LED/Sensor	Integrated IR LED/Sensor	Flex Resistor
Power Consumption (0.6)	3	3	4.2
Components (0.4)	0.8	1.6	2
Reliability (0.8)	4.8	5.6	0.8
Implementation (0.3)	0.9	1.5	2.4
TOTAL	9.5	11.7	9.4

4.2 Battery

For the selection of type of battery, the initial cost (development and prototyping) and long-term cost (for the end-user) were separated with the long-term cost given a slightly higher weight. Ease of implementation was considered to be the most important aspect of the design, followed closely by convenience. Convenience was defined by the case being operational during the battery replacement/charging period. Lastly, interaction was included to rate the amount the case would be handled during the battery replacement/charging period. Results of the design matrix for various types of battery are summarized in Table II. From the results shown in Table II, it is concluded that the "wall-charge Li" battery gained the highest score.

Table II. Design matrix for various types of battery.

Design Factor (Weight)	Battery Type		
	Replaceable Batteries	Removable Li	Wall-Charge Li
Initial Cost (0.3)	2.1	0.9	0.9
Long-term Cost (0.4)	0.8	3.2	3.2
Interaction (0.2)	0.4	0.4	1.6
Convenience (0.5)	2	1	3.5
Implementation (0.6)	3.6	3.6	2.4
TOTAL	8.9	9.1	11.6

4.3 Locking Mechanism Matrix

Again, the design factors in this case were weighted according to their importance with power consumption at the top of the list, followed closely by physical strength of the lock. Ease of implementation was a moderate consideration and the cost of the design was taken into account as well. Results of the design matrix for various locking mechanisms are summarized in Table III. From the results shown in Table III, it is concluded that the "linear actuator" mechanism gained the gained the highest score.

Table III. Design matrix for various locking mechanisms.

Design Factor (Weight)	Locking Mechanism	
	Magnetic	Linear Actuator
Power (0.7)	1.4	3.5
Cost (0.3)	1.5	1.2
Strength (0.6)	2.4	4.2
Implementation (0.5)	1.5	2
TOTAL	6.8	10.9

5.0 Final Design

The final design of the Pack Pal system must integrate the electronic circuits with all the aforementioned sensors, indicators, buttons and the Bluetooth module and other components into a handheld case. A preliminary SolidWorks model of the system can be seen below. The integrated IR/LED sensors will be used to sense the number of cigarettes in the case. In addition, there will be two LED indicators; one to indicate whether the case is unlocked and another to indicate the power level of the semi-permanent Lithium ion battery.
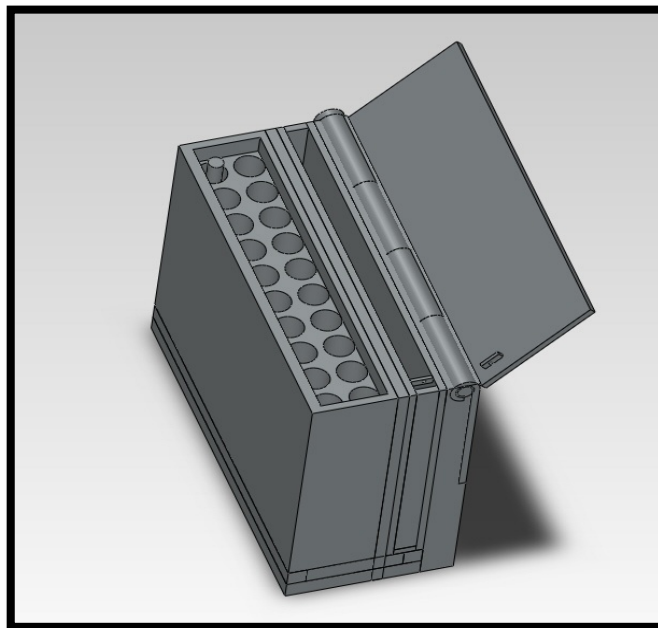
Figure 3. This is a figure of the Solidworks model of the Pack Pal system.

The Pack Pal system will be controlled via a microcontroller, which will gather the data from each access attempt and send it wirelessly to the smartphone via the Bluetooth module. The system will be powered via a wall chargeable Lithium ion battery. The case will lock via a linear actuator mechanism. The phone application will log data, analyze, and display it for the user and support contacts. The final design of the Pack Pal system will have to integrate all aspects of this design into a usable case while accompanying the smartphone application. A block diagram of the hardware components of the Pack Pal system can be found in Appendix A.5, Fig. A5-1 showing how all the aspects of the system will interact.
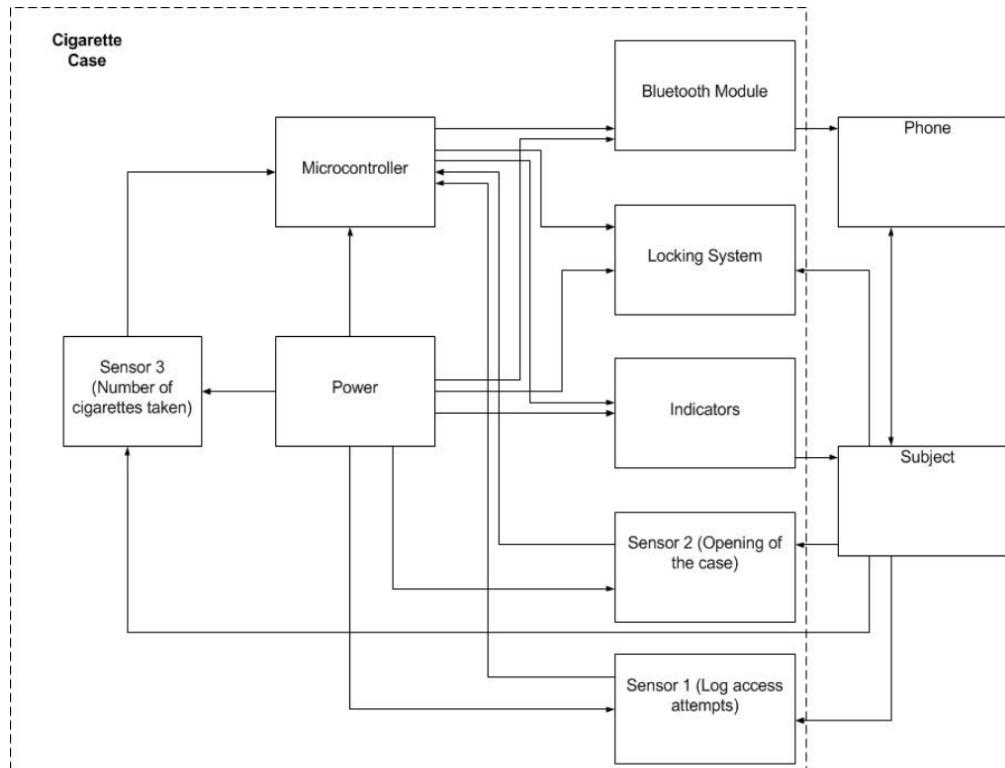
Figure 4. A block diagram of the hardware components of the Pack Pal System

5.1 Cigarette Sensing

The sensing of how many cigarettes are in the case will be accomplished via an array of IR LED sensors. These sensors are electronic components called QRD114 each of which consists of a combined infrared LED and phototransistor. Technical specifications for these sensors can be found in Appendix A.1.

Transistors are used the design of the sensor circuit to aid in power consumption. A transistor can function as a digital switch, connecting a power supply to a component when it receives a signal. In this manner a much smaller signal can be used to trigger a much larger signal. This function allows for significant power saving. The Pack Pal system implements transistor switching to save power by

only supplying power to the sensor array circuit for an instant just long enough to read the status of the sensors and then shut off.

5.2 Battery

The battery will be a semi-permanent lithium ion battery that will accommodate wall charging and removal from the case for ease of use. It lasts about eight hours providing normal operating conditions for the Pack Pal system.

5.3 Locking Mechanism

The locking of the case will be accomplished by a linear actuator. The actuator will be (under normal operating conditions) slid into two overlapping loops from the bottom and top of the case effectively, preventing the case from being opened. Upon receipt of a signal (by pressing a push button to open the case), a timer will commence and after a specified time delay, the actuator will retract from these two loops and the case will be unlocked.

5.4 Microcontroller

All of the electronic components will be controlled by a microcontroller. The code for the cigarette-sensing demo can be found in Appendix A.9. The microcontroller will utilize interrupts to minimize overall power consumption and minimize code complexity. Interrupts help minimize power utilization by allowing the microcontroller to be in a sleeping state until an interrupt is received. This concept is the central part of the microcontroller code design. Once interrupted, the microcontroller will execute a function that locks the case for the specified amount of time and then allows the patient to access the cigarettes. It will then count the number of cigarettes taken after the case locks again and transmit this data to the smartphone application via Bluetooth. After the counting function completes, the microcontroller will return to sleep mode.
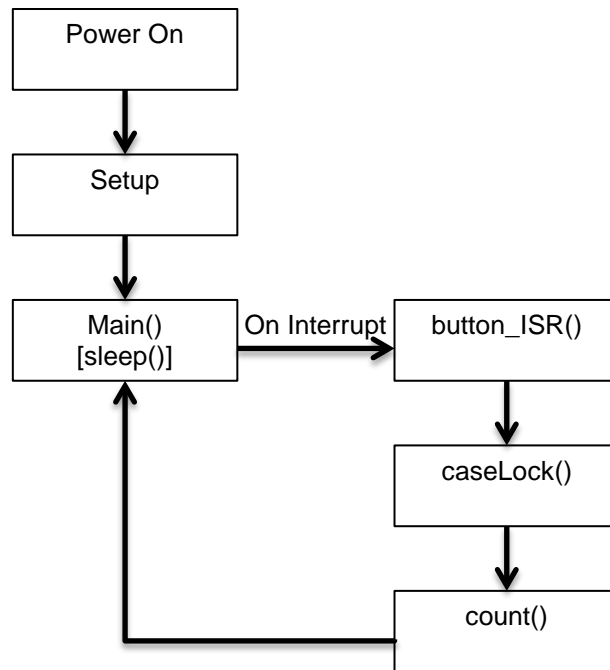
Figure 5. This block diagram represents the microcontroller code.

5.5 Applications

The smartphone application will be developed for Android phones and will be specifically tailored for SMI patients. The application will take the data sent from the case and format it appropriately. A copy of the formatted data will be reported to the healthcare professional involved in the quit attempt while all of the raw data are kept in a memory for future user. Data will also be formatted in an easily accessible and understandable manner for the users so that they can monitor their progress throughout the quit attempt. A block diagram of the application software can be found in Appendix A.5, displaying how all the aspects of the application will interact).

5.5.1 Data Storage

An important piece of the application is how to store every time the user tries to open the case, when the case actually opens, and how many cigarettes were taken. This data must then be stored and sorted in their respective lists.

Every time the case receives stimuli from the user, a new object is made with a Date. There are two different types of Date objects in Java. One counts the milliseconds since 1970, and the other is made of a date and time that looks like this:

Sun Dec 09 11:21:38 CST 2012

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It was decided that the second Date object would more practical to use because the milliseconds from 1970 is not very useful for this project. In the Attempt class, there are methods to retrieve the year, month, day, and time for any Date object.

When the user pushes the button to open the case, a ButtonPress object is made. This object has a Date object, a String trigger, and an integer rating. When the button is pressed, the user is sent a message on his or her smartphone asking the user to write the cause of the craving to smoke and to rate how bad the craving is on a scale of 1-10. The String trigger stores cause of the craving and the integer rating stores the user's rate of the craving. There are methods in the ButtonPress class that makes it possible to retrieve the Date object, trigger, and integer for any ButtonPress object.

When the case opens, a CaseOpen object is made that only stores a Date object. There is a method in the CaseOpen class that makes it possible to retrieve the Date object for any CaseOpen object.

When cigarettes are taken out the case, a CigTaken object is made. CigTaken has a Date object along with an integer numCig that stores the number of cigarettes taken. There are methods in the CaseOpen class that makes it possible to retrieve the Date and the integer numCig for any CigTaken object.

ButtonPress, CaseOpen, and CigTaken each have their own separate ArrayList in which those objects are stored. As soon as a new object is created, it is sent to its respective ArrayList to be stored. However, it is important that the Array lists be sorted in chronological order. A sort method is used to compare each new object to the other objects in its ArrayList and puts the new object in the correct location in the list.

For future work, each ArrayList will be written to a file that can be easily transferred from the smartphone to a computer so that the information in the file can be manipulated to form spreadsheets and graphs for statistical analysis.

```
                          ┌─────────────────────────────┐
                          │           Stimuli           │
                          │                             │
                          │  Button is pressed, case    │
                          │  opens, or cigarettes are   │
                          │           taken             │
                          └─────────────────────────────┘
```

If Button is pressed   If case is   If cigarettes are taken
                              opened

```
┌──────────────────┐    ┌──────────────────┐    ┌──────────────────┐
│ New ButtonPress  │    │  New CaseOpen    │    │  New CigTaken    │
│     object       │    │     object       │    │     object       │
│                  │    │                  │    │                  │
│ Date date        │    │ Date date        │    │ Date date        │
│ String trigger   │    │                  │    │ int numCigs      │
│ int rating       │    │                  │    │                  │
└──────────────────┘    └──────────────────┘    └──────────────────┘

┌──────────────────┐                            ┌──────────────────┐
│ User is asked to │                            │ User is asked how│
│ write what       │                            │ many cigarettes  │
│ caused the urge  │                            │ taken            │
│ to smoke         │                            │ -Stored in numCig│
│ -Stored in       │                            │                  │
│ String trigger   │                            └──────────────────┘
│                  │
└──────────────────┘

┌──────────────────┐
│ User is asked to │
│ rate urge        │
│ -Stored in int   │
│ rating           │
│                  │
└──────────────────┘

┌──────────────────┐    ┌──────────────────┐    ┌──────────────────┐
│     Sort()       │    │     Sort()       │    │     Sort()       │
└──────────────────┘    └──────────────────┘    └──────────────────┘

┌──────────────────┐    ┌──────────────────┐    ┌──────────────────┐
│ AddButtonPress() │    │  AddCaseOpen()   │    │  AddCigTaken()   │
└──────────────────┘    └──────────────────┘    └──────────────────┘
```
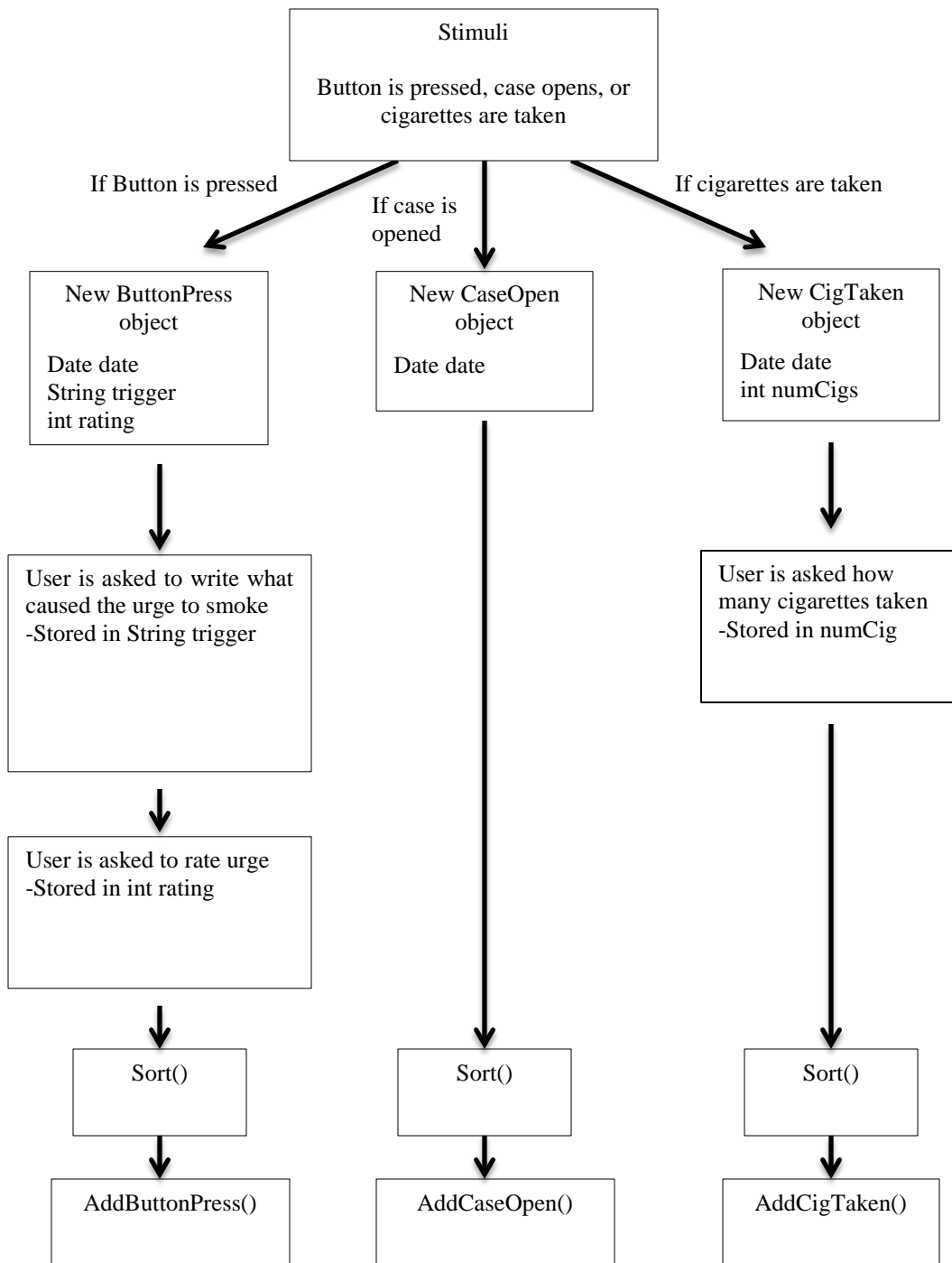
Figure 6. This is a block diagram of the data storage section of the application code.

6.0 Testing

For this portion of the project there was not significant testing involved in the area of data collection and analysis. Most testing done was in the form of hardware validation, verification, and debugging. For the microcontroller, testing of each pin used in the final prototype was done separately. For the analog input pins a known voltage was placed on the pin and read by the Analog-to-Digital converter (ADC). This made it simple to tell if the voltages were being read properly. The interrupt was tested by hooking a button up to the pin used to listen for the interrupt signal (p5) and attempting to trigger an interrupt. All other digital output pins were simply measured with the multi-meter to confirm they were outputting the correct voltage. The circuit was tested by reading the output of the IR sensors while covered and uncovered. This difference is what was used in the final microcontroller code to determine whether a cigarette was present or not. When the system was completely assembled, testing consisted of verifying the proper reaction to a button being pressed, multiple access attempts in a short period of time, the presence of a cigarette, and proper Bluetooth communication. If an issue was found, it was debugged and then tested again.

7.0 Conclusion

The development of the Pack Pal system involved several iterations and improvements. This system will provide an important service to individuals with metal illness who are addicted to nicotine because it will be a program tailored directly to their needs. The iterative process of design allowed the team to incrementally design each aspect of the design.

The progression of the Pack Pal system is reflected in each step of the design. First, the team worked to developed a case that mimicked a metal cigarette case. In this design many parts were to be made by the team including the linear actuator and the PCB. As the design progressed important changes were made both in the form factor of the design and in the implementation of the particular components of the case. The design evolved as components were found to accomplish the essential tasks (linear actuator) and the overall design reflected these changes. The individual complexities of the design were simplified through this process. By driving the design through this series of iterations and countless smaller iterations a more complete vision of the design began to emerge. From here the team focused on turning the theory of the design in to a reality by combining all the separate parts into one cohesive design.

The current design for the Pack Pal is a functional prototype. This is an important first step because it proves the viability and feasibility of the design. In the future, it will be essential to improve in this design in order implement a final finished product.

8.0 Future Work

8.1 Case Design

The physical layout and design of the circuit still need to be established. In the development of this design it will be important to consider the particular needs of the users (SMI patients). This design will have fit up to 20 cigarettes and the electronics of the circuit. Currently the team has developed two distinct designs and form factors that accomplish the design requirements and specifications.

8.1.1 Cigarette Pack

Further modifications of thickness of materials and sizes of parts will happen as force testing is applied to the case design.

8.1.2 Cigarette Case

Due to the disadvantages discussed in section 3.4.2, further modifications to this design have been terminated, as this design will not be the final case design.

8.1.3 Geneva Gear

Using a Geneva Gear as the central part of the design is a possibility for future work. The Geneva gear is a mechanical system that translates continuous rotational motion to an intermittent rotary motion (see figure 3 below). A knob on the outside of the case would provide the continuous rotational motion. When this knob is turned (and the case is unlocked) the case will rotate to allow one cigarette to be exposed at a time. This design has a few beneficial features over our current design. First, the Geneva gear design only allows access to one cigarette at a time. By only allowing access to one cigarette at a time the case will only need to have one sensor which will greatly minimize the power consumption and complexity of the sensing circuit. Second, the Geneva gear would be made of plastic and not require the case to have exposed moving parts like a hinge. These features would make the case lighter and simplify the locking mechanism. To lock the case a shaft would have to interrupt the progress of the rotational gear. The downside to this design is the additional machining complexity involved in creating a moving gear system. This complexity may require the team to search for professional fabrication assistance. Further research, modeling and design considerations will need to be pursued to determine the feasibility of this design.
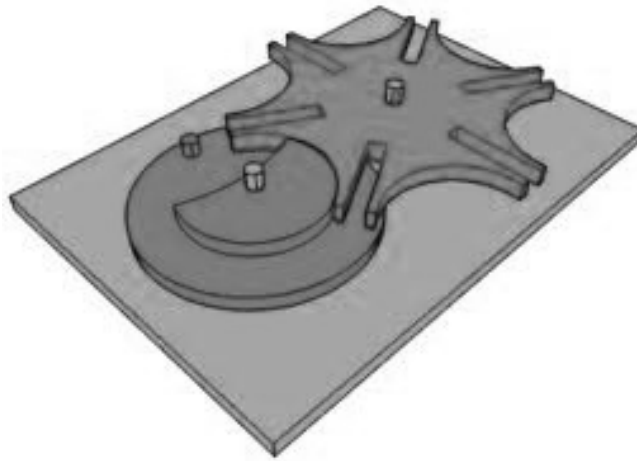
Figure 7: The mechanism for the Geneva gear also known as Maltese cross (10).

8.2 Electronics

The first step in the design of the circuit is to complete a fully functional breadboard circuit that accomplished all the goals specified above (see section 2.0 for design specifications). Then assessments of power requirements can be made on this circuit to determine the type of battery to power all components. This circuit can be made more permanent on a wire wrapped board to establish a more concrete product. Finally after testing the circuit for functionality and power behavior (battery life etc.) it can be sent for printed circuit board (PCB) printing. This PCB version of the circuit will be much smaller and can be fitted inside the completed case. A computer design of the PCB can be found in Appendix A.5.

8.3 Application

The mobile application must be developed based on specifications from our client and from our design specifications above (section 2.0).

9.0 **References**

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http://blog.dugnorth.com/2008/04/geneva-mechanism-maltese-cross-or.html.

10.0 Appendix

Appendix A.1:
Technical Specifications for Integrated IR LED Sensor QRD 1114

Emitter

    Maximum Forward Voltage: 1.7V
    Maximum Reverse Voltage: 5V
    Maximum Reverse Current: 100 μA

Sensor

    Dark Current: 100 nA

Appendix A.2:

Design of a Device to Help Severely Mentally Ill Patients Quit Smoking
Product Design Specifications

Client: Prof. Gustafson, Prof. Ferron, Prof. Brunette
Advisor: Dr. Nimunkar
Team:

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Date: October 21, 2012

Problem Statement

To design a case for holding cigarettes that is augmented to specifically help people with severe mentally illness(SMI) quit smoking. The case will house a sensor to detect if the user attempts to open the case, another sensor to detect whether the case was actually opened and a third sensor will be used to detect how many cigarettes were removed from the case. The data from access attempts will be continuously transmitted to the smartphone wirelessly. The data will be transmitted to the phone via bluetooth (v4.0) as serial characters coding for various responses to sensors. For example, the character 'a', would represent access to the case. The phone will detect access attempts, opening and closing. Each time the user accesses the case, the phone application will ask the user a series of questions about their desire to smoke, the environemental or emotional cue that prompted the urge, and to rate the salience of the urge. Overtime, the user will gain knowledge about their own use and will then be able to use skills (aquired via the application) to cope with not having a cigarette. One of these skills could be to do something else (play a video game, listen to music or do another activity the participant has indicated helps them avoid smoking) or remind them of the reasons that they want to quit (display a picture of their child, pet or loved one). In addition, the application will send daily updates to the subject and/or to any clinician or provider the subject specifies.

1. Client Requirements

- The case should be difficult to break and hold at least 20 cigarettes (should be modeled after the cases in current use).
- The case should have an onboard rechargeable battery.
- The case should unlock after a request from the participant via a push button after a specified time delay. Then the case will send this information to the cell phone application via Bluetooth.

- The system should interact (can be through phone) with the user to help track behaviors, beliefs, and urges around smoking and support coping skills. The electronic pack should lock for a time delay specified by research on SMI patients who smoke. While the case is locked the subject is to engage in coping skills to delay and reduce smoking.
- The device and the application should be easy to use, with simple opening/closing mechanism, uncluttered interface on phone, simple text, minimal layers of navigation, minimal requirements for abstract thinking and memory.
- We should have a working prototype (five copies) done in Spring 2013.

2. Design requirements
2.1 Physical and Operational Characteristics
a. *Performance requirements*:
The device is required to be augmented for daily and frequent use. Severely mentally ill patients may attempt to access it in different time delays that vary from few minutes or sometimes few seconds in the case of severe addiction to few hours in less severe cases.

b. *Safety*:
The cigarette case should be developed for mentally ill patients so it should be totally safe and free of warnings because we cannot rely on the patient to take precautions.

c. *Accuracy and Reliability*:
The case should record and send reliable data about the access times the opening of the case and the number of cigarettes taken because this information can lead to faulty interpretations if it lacks accuracy. For example if the open button is pressed but the patient did not open the case because he controlled his urge but the data collected showed that the case was opened this will affect the treatment.

d. *Life in Service*:
This case should serve the patient for the whole period of the treatment and remain useful after the treatment is done for future uses. It should work in different countries and operate 24/7 but the battery needs to be recharged every 8 hours.

e. *Shelf Life*:
The battery that is included in the case should be a rechargeable battery for efficiency and ease of use and also because it is more environmentally friendly.

f. *Operating Environment:*
The cigarette case must adapt to different working environments. It can be exposed to different temperatures and different humidity ranges. It can also be exposed to dust, vibrations and accidental hits. We have to make sure that the accuracy of the data is not affected by those factors.

2.2 Production Characteristics

    a. *Quantity*:
        We should have five devices for the research purpose.

    b. *Target Product Cost:*
        The cost of this cigarette case will be higher than the cost of a normal cigarette case but it has to be a feasible price not above 100$. The case will be purchased once only and it can be refilled with cigarettes so this is an initial cost only.

2.3 Miscellaneous

    a. *Patient-related concerns:*
        The patients we are dealing with are mentally ill patients so extra considerations should be taken into account regarding the system so it is tailored to the needs of the users. The collected data should be confidential and provided only to a specified mentor, clinician and a system administrator.
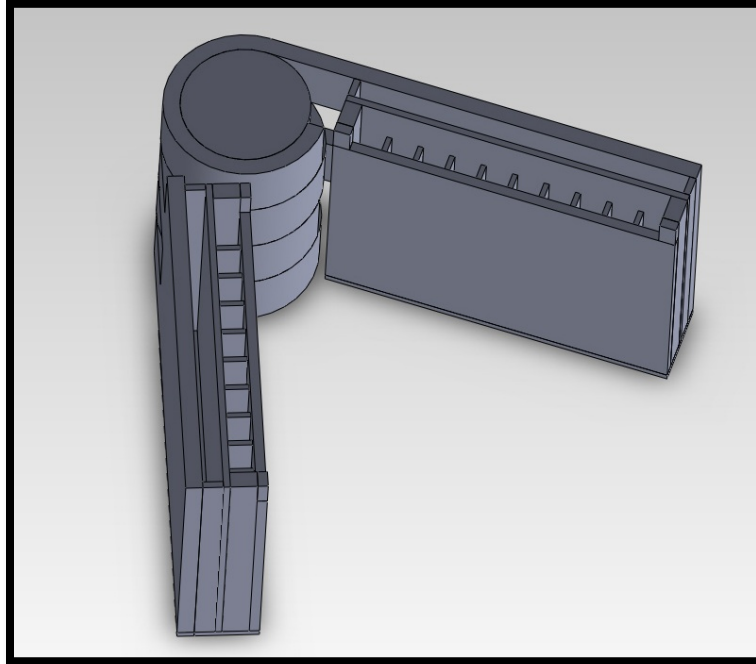
Fig. A3. A preliminary Solid Works model of the Pack Pal system.
This Design was no longer pursued as a viable option.
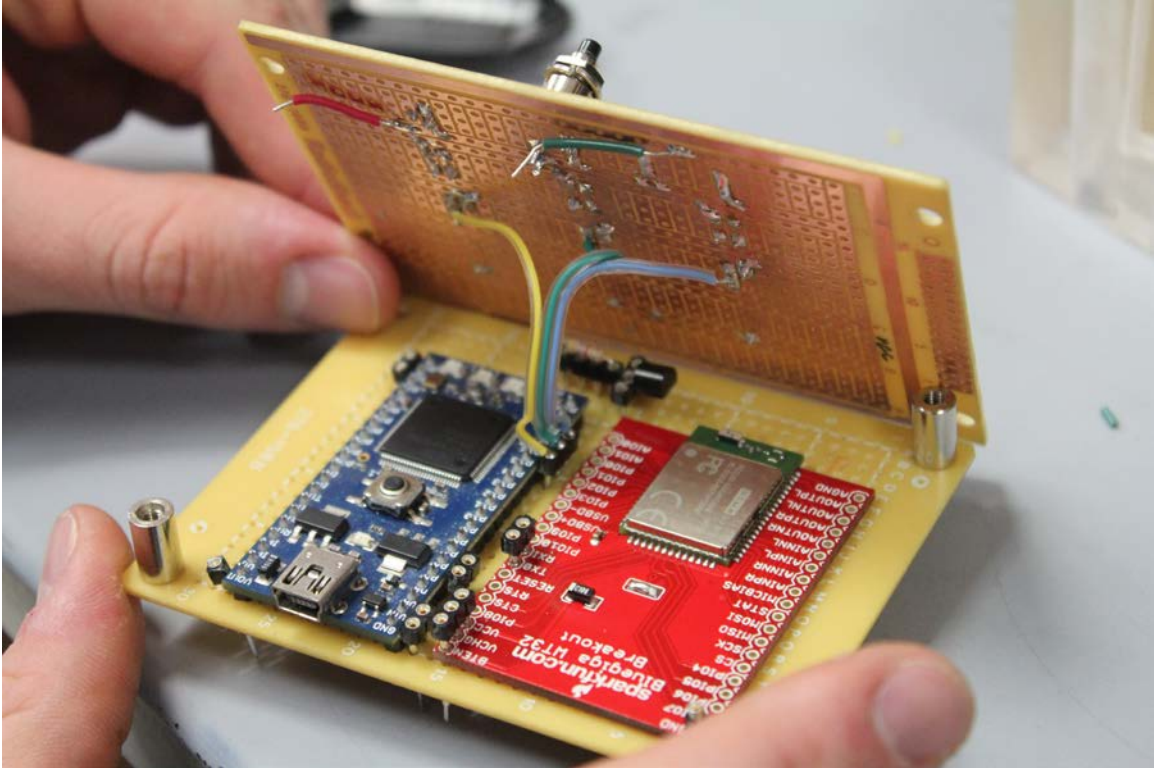
Fig. A4. A picture of the breadboard mounted electronic circuitry of the Pack Pal system.
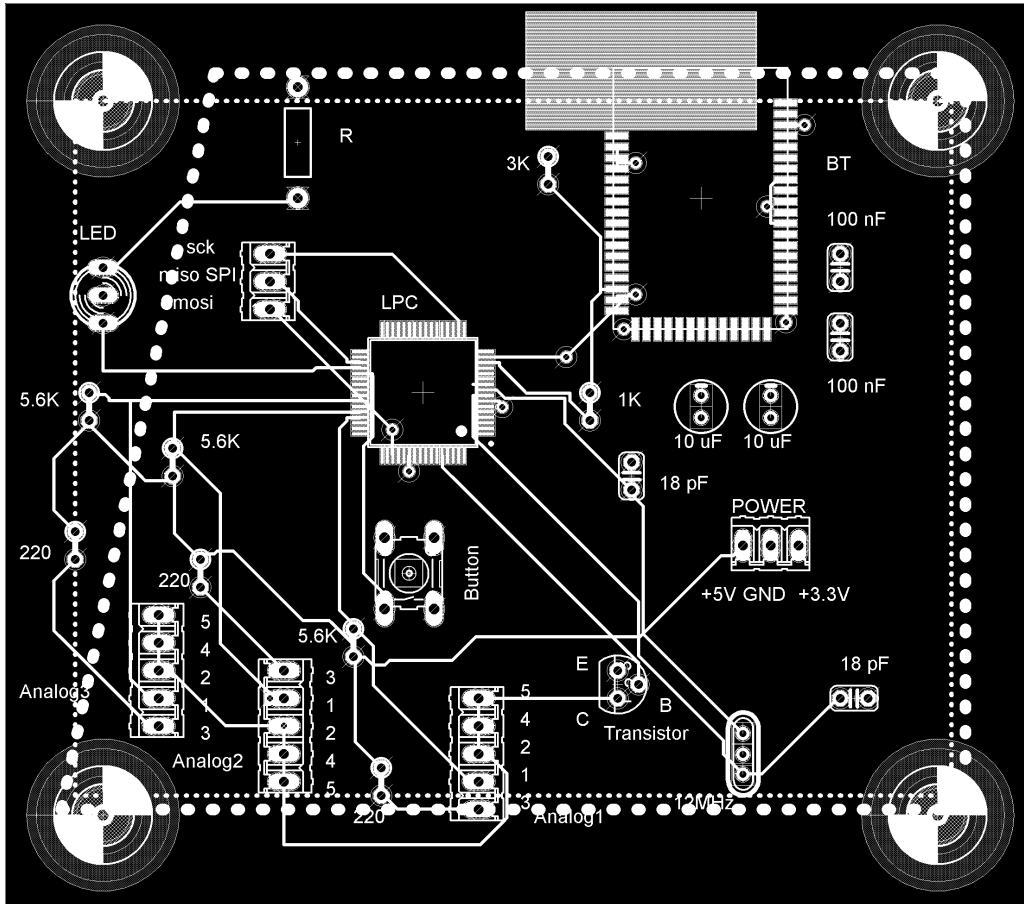
Figure A.5. A PCB design for the electronics of the Pack Pal
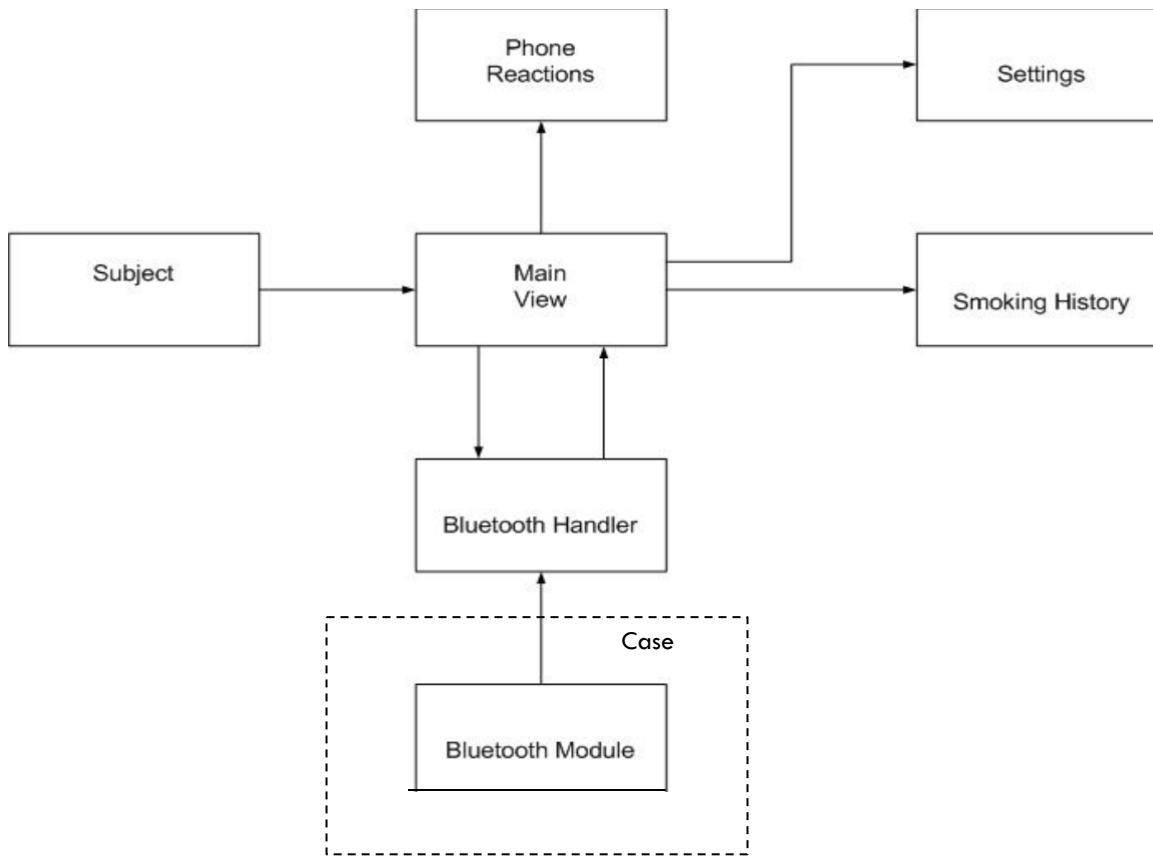
Appendix A.6:
Block Diagrams

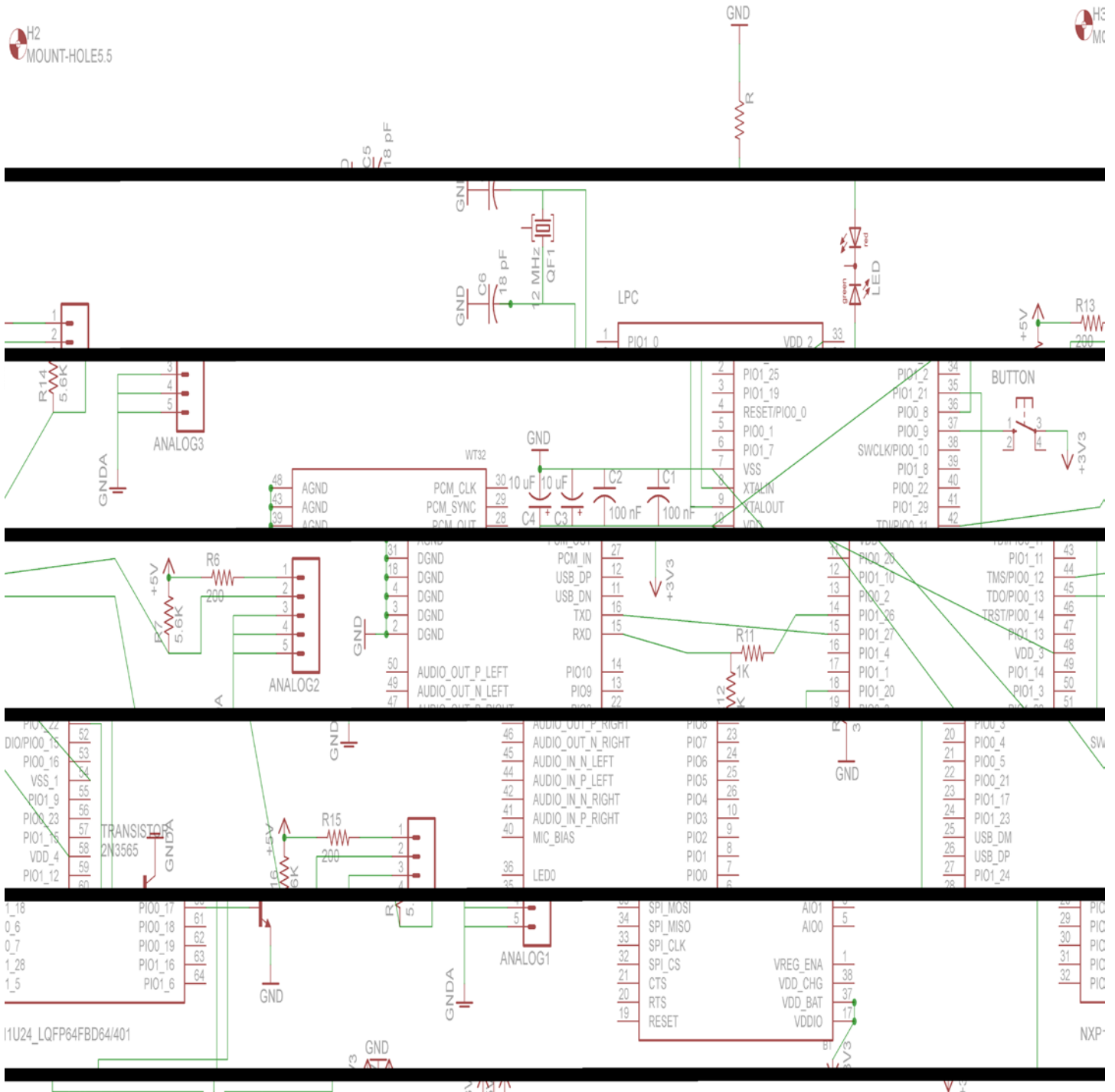Fig. A6. A block diagram of the software modules of the Pack Pal system.

Figure A7. Schematic of the electronic circuits with three IR LED sensor.

Appendix A.8
Data Storage Code

AddToList

```java
package SmartphoneStorage;
import java.util.ArrayList;
import java.util.Date;

public class AddToList {

        public static ArrayList <CaseOpen> caseOpen = new ArrayList<CaseOpen>();
        public static ArrayList <CigTaken> cigTaken = new ArrayList<CigTaken>();
        public static ArrayList <ButtonPress> buttonPress = new ArrayList<ButtonPress>();

        /**
         * This method adds an attempt to the buttonPress ArrayList.
         * @param attempt
         */
        public static void addButtonPress(ButtonPress attempt){
                int type = 1;
                Date date = attempt.getDate();
                Storage.sort(buttonPress, date, type);
                buttonPress.add(Storage.index, attempt);
        }

        /**
         * This method adds an attempt to the caseOpen ArrayList
         * @param attempt
         */
        public static void addCaseOpen(CaseOpen attempt){
                int type = 2;
                Date date = attempt.getDate();
                Storage.sort(caseOpen, date, type);
                caseOpen.add(Storage.index, attempt);
        }

        /**
         * This method adds an attempt to the cigTaken ArrayList
         * @param attempt
         */
        public static void addCigTaken(CigTaken attempt){
                int type = 3;
                Date date = attempt.getDate();
                Storage.sort(cigTaken, date, type);
                cigTaken.add(Storage.index, attempt);
        }
}
```

```java
package SmartphoneStorage;
import java.util.Date;

public class Attempt {

        public static Date getDate(Date date){
                return date;
        }

        /**
         * This method returns the time of the date
         * @param date1
         * @return The time of the date (String)
         */
        public static String getTime(Date date1){
                String date = date1.toString();
                String time = " ";
                boolean keepGoing = true;
                while(keepGoing){
                        for(int i = 0; i < date.length(); i++){
                                if(date.charAt(i) == ':' ){
                                        time = date.substring(i - 5, i + 3);
                                        keepGoing = false;
                                }
                        }
                }
                return time;
        }

        /**
         * This method returns the month of the date
         * @param date1
         * @return The month of the date (int)
         */
        public static int getMonth(Date date1){
                String date = date1.toString();
                String monthString = date.substring(4,7);
                int month = 0;
                if(monthString.equals("Jan")){
                        month = 1;
                        return 1;
                }
                if(monthString.equals("Feb")){
                        month = 2;
                        return 2;
                }
                if(monthString.equals("Mar")){
                        month = 3;
                        return 3;
```

```java
        }
        if(monthString.equals("Apr")){
            month = 4;
            return 4;
        }
        if(monthString.equals("May")){
            month = 5;
            return 5;
        }
        if(monthString.equals("Jun")){
            month = 6;
            return 6;
        }
        if(monthString.equals("Jul")){
            month = 7;
            return 7;
        }
        if(monthString.equals("Aug")){
            month = 8;
            return 8;
        }
        if(monthString.equals("Sep")){
            month = 9;
            return 9;
        }
        if(monthString.equals("Oct")){
            month = 10;
            return 10;
        }
        if(monthString.equals("Nov")){
            month = 11;
            return 11;
        }
        if(monthString.equals("Dec")){
            month = 12;
            return 12;
        }
        else{
            return 0;
        }
}

/**
 * This method returns the year of the date
 * @param date1
 * @return The year of the date (int)
 */
public static int getYear(Date date1){
        String date = date1.toString();
        String yearString = date.substring(24,28);
        int year = Integer.parseInt(yearString);
```

```java
                return year;
        }

        /**
         * This method returns the day of the date
         * @param date1
         * @return The day of the date (int)
         */
        public static int getDay(Date date1){
                String date = date1.toString();
                String dayString = date.substring(8,10);
                int day = Integer.parseInt(dayString);
                return day;
        }
}
```

ButtonPress

```java
package SmartphoneStorage;
import java.util.Date;

public class ButtonPress {

        private Date date;
        private String trigger;
        private int rating;

        public ButtonPress(Date date, String trigger, int rating){
                this.date = date;
                this.trigger = trigger;
                this.rating = rating;
        }

        public Date getDate(){
                return date;
        }
        public void setDate(Date date1){
                date = date1;
        }

        public String getTrigger(){
                return trigger;
        }

        public void setTrigger(String trigger1){
                trigger = trigger1;
        }

        public int getRating(){
                return rating;
        }
```

```java
        public void setRating(int rating1){
                rating = rating1;
        }

        public String toString(){
                return "\n" + "Date: " + getDate() + "\n" + "Trigger: " + getTrigger() + "\n" +
                "Rating: " + getRating() + "\n";
        }
}
```

CaseOpen

```java
package SmartphoneStorage;
import java.util.Date;

public class CaseOpen {

        private Date date;

        public CaseOpen(Date date){
                this.date = date;
        }

        public Date getDate(){
                return date;
        }

        public void setDate(Date date1){
                date = date1;
        }

        public String toString(){
                return "\n" + "Date: " + date + "\n";
        }
}
```

CigTaken

```java
package SmartphoneStorage;
import java.util.Date;

public class CigTaken {

        private int numCigs;
        private Date date;

        public CigTaken(int numCigs, Date date){
                this.numCigs = numCigs;
                this.date = date;
        }
```

```java
        public int getNumCigs(){
                return numCigs;
        }
        public void setNumCigs(int numCigs1){
                numCigs = numCigs1;
        }

        public Date getDate(){
                return date;
        }

        public void setDate(Date date1){
                date = date1;
        }

        public String toString(){
                return "\n" + "Date: " + getDate() + "\n" + "Number of Cigarettes Taken: " +
                getNumCigs() + "\n";
        }
}
```

Storage

```java
package SmartphoneStorage;
import java.util.ArrayList;
import java.util.Date;

public class Storage {

        public ArrayList <Date> dates = new ArrayList<Date>();
        public static int index = 0;

        public Storage(ArrayList dates){
                this.dates = dates;
        }

        /**
         * This method compares two dates.
         * If date1 > date2, the method returns 1.
         * If date1 = date2, the method returns 0.
         * If date1 < date2, the method returns -1.
         * @param date1
         * @param date2
         * @return Result of the comparison
         */
        public static int compareTo(Date date1, Date date2){
                int result = date1.compareTo(date2);
                return result;
        }
```

```java
/**
 * Puts the date of the attempt in its proper place in its respective ArrayList.
 * There is a warning in this method because the type of ArrayList is not specified.
 * This is done so that this method would work for all three different types of ArrayLists
 * (buttonPress, caseOpen, cigTaken)
 */
public static void sort(ArrayList list, Date date, int type){
        if(list.size() == 0){
                index = 0;
        }
        else{
          boolean keepGoing = true;
          for(int i = 0; i < list.size(); i++){
            if(keepGoing){
              if(type == 1){
                  int compare = compareTo(date, AddToList.buttonPress.get(i).getDate());
                    if(compare <= 0){
                            index = i;
                            keepGoing = false;
                    }
              }
              if(type == 2){
                  int compare = compareTo(date, AddToList.caseOpen.get(i).getDate());
                    if(compare <= 0){
                      index = i;
                      keepGoing = false;
                    }
              }
              if(type == 3){
                  int compare = compareTo(date, AddToList.cigTaken.get(i).getDate());
                    if(compare <= 0){
                      index = i;
                      keepGoing = false;
                    }
              }
            }
          }
        }
}
}
```

Appendix A.9
Demo Microcontroller Code

```
#include "mbed.h"
#include "PowerControl/EthernetPowerControl.h"
#include "PowerControl/PowerControl.h"

void button_isr();  // Declare button interrupt service routine
void caseLock();   // declare caselock Function
void count();  // declare count function

int int_enable;  // declare enable (interrupt lock) bit.

AnalogIn c0(p15);  // enable all three Analog input pins.
AnalogIn c1(p16);  // There will be more in the final device
AnalogIn c2(p17);

AnalogIn sensors[3] = {c0, c1, c2}; // This array is used to iterate
                        // through the sensors during counting

DigitalOut myled(LED1); // These two LED's are used for debugging purposes
DigitalOut locked(LED2);

DigitalOut act(p21); // Digital Output controlling the acuator motion

DigitalOut strans(p23); // Digital output controlling the transistor
                // that supplies power to the sensors

InterruptIn button(p5); // Declare pin 5 as an interrupt
DigitalIn button_poll(p5); // Also declare pin 5 as a Digital input for polling

Serial wt_32(p9, p10); // tx, rx: used for bt communication
Serial pc(USBTX, USBRX); // Used for pc debugging

// A function that powers downt he external usb device to save energy.
#define USR_POWERDOWN    (0x104)
int semihost_powerdown() {
   uint32_t arg;
   return __semihost(USR_POWERDOWN, &arg);
}


int main() {

   act = 0; // initialize all variables used.
   strans = 0;
```

```
    int_enable = 1;

    PHY_PowerDown(); //Power down the ethernet device to save energy

    int result = semihost_powerdown(); //Power down external usb

    button.rise(&button_isr); // Set the button interrupt to occur
                       // on the rising edge and have it jump
                       // to the address of the button_isr function

    wt_32.baud(115200);  // Set the baud rate to 115200 for bluetooth
    myled = 1;//
    locked = 1; //Signifiea the case is locked

    // Enter an infinite loop that sets the mController to sleep and
    // resets some variables
    while(1) {
        wait_ms(10);
        locked = 1;
        act = 0;
        int_enable = 1;
        Sleep();
    }
}


void button_isr(){
    wait_ms(15); // Wait for bouncing to stop

    // Ensure that the button is still pressed AND the interrupt isn's
    // locked.
    if(button_poll.read() && int_enable){

        int_enable = 0; // "Lock" the interrupt so an interrupt
                   // can't occur while another interrupt is
                   // happening.

        caseLock(); // Call the caseLock() function
    }
}


void caseLock(){
    pc.printf("In caseLock()\r\n");

    // Transmit an 'a' character to signify the case was accessed.
```

```
    wt_32.putc('a');
    while(!wt_32.writeable()){ /* wait */}
    wt_32.putc(10);
    while(!wt_32.writeable()){ /* wait */}
    wt_32.putc(13);

    pc.printf("Waiting...\r\n");
    //wait(10);

    pc.printf("Unlocked!\r\n");

    locked = 0;
    act = 1;

    //wait(30);

    pc.printf("Locked!\r\n");

    count(); // Call the count function tp count remaining cigarettes
}


void count(){
    int counter = 0; // initialize the counter to zero
    int i; // Declare other variables to be used.
    float val;
    AnalogIn *curr; // This variable is a pointer to an AnalogIn object

    strans = 1; // Enable the sensors to be powered
    wait_us(150); // Ensures the sensors are fully powered

    // For each sensor in the array
    for(i = 0; i < 3; i++){
        curr = &(sensors[i]); // Point to the current sensor

        val = (curr->read())*3.3; // Determine the voltage between 0 and 3.3V

        pc.printf("c%i: %f\r\n", i, val); // print to pc
        wait_us(20);

        // If the analog value is greater than 2V, increment the counter
        if(val > 2.0){
            counter++;
        }
    }
```

```
    // transmit the number of cigarettes in the case.  This value can be compared
    // with the previous value to determine the number of cigarettes taken.
    wt_32.printf("%i", counter);
    while(!wt_32.writeable()){ /* wait */}
    wt_32.putc('\r');
    while(!wt_32.writeable()){ /* wait */}
    wt_32.putc('\n');

    strans = 0; // Disable power to the sensors
}
```