Pill Pall: A Medication Tracker and Dispenser

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1 Introduction

1.1 Objective

Modern medicine allows us to alleviate the ailments that come with advanced age and has consequently allowed us to extend our life expectancy well beyond limits decades ago. As expected, reaping the benefits of old age requires us to maintain regularly scheduled medication intake. Older generations have an especially difficult experience keeping track of pills taken and they may have many different pills to take at different times of the day. Additionally, people can be forgetful and miss important medication with differing frequencies of intake. Thus, it may be seen that overall control of specific medication taken at a time and the remembrance of taking such batches of medication proves to be a challenge for the elderly. Complications with medication, whether it be overdosing, underdosing, or mismanagement, are potentially dangerous. To design around such a dilemma, we propose an automatic medication tracker and dispenser for user-caregiver pairs.

We propose an automated pill dispensing system that will inform users when to take their pills and indicate whether the pill(s) has/have been taken or not. Additionally, to prevent overdose, the dispensing system would be able to lock and only dispense medication at the right time of day and when the single user has not already taken the pill(s). There will be an interface for caregivers to configure and show the frequency of intake for specific pills. This will be configured on the interface such that pills with specific frequencies will only dispense should the time to take them be ready. Alerts and notifications should also be supplemented with the device to remind users to take the batch of medicine. For those that are not in frequent control of a technological interface, the device will notify users to take medication by use of lights.

1.2 Background

Efforts by commercial manufacturers on Today's market effectively dispense medication of different types with configuration options possible, but at high price points and fail to track the taking of medication. Configurations in our design will be through a remote application used by caregivers, to avoid running the risk of medication mismanagement by users. Pills in Pill Pal are not only dispensed by schedule and necessary doses, but also tracked such that caregivers will be able to see if the pills have been retrieved by their intended users. With growing numbers of an elderly population in the United States[2], it is anticipated that there will be more elders than caregivers in the coming years. Our proposed solution aims to tackle the problem of remote care with the tracking and dispensing feature. Caregivers will be able to survey the medication intake of patients without 24/7 attention, and will free up time for greater volumes of patients or other issues, without the mundane chore of manual dose control. Besides regular attention, responsible drug consumption also continues to be a foremost challenge for caregivers. For increased safety, our project takes the issue of drug abuse and medication tampering into consideration by also featuring a fail-secure lock.

Former projects similar to ours struggled mechanically where dispensing was a concern. Groups implemented a number of new and related solutions without success on control over the number of pills dispensed. To circumvent this technicality, we will be working closely with the ECE Machine Shop to implement a horizontally sorting pill counter with the use of an IR sensor much like automatic pill counters seen on markets today[3]. We believe that this will be a greater improvement on a vertical gravity-based pill drop dispenser. Our project models on existing solutions, to motivate greater chances of success on dosage control.

1.3 High-Level Requirements

1. Caregiver inputs the prescription specification of the medication into the mobile application. This information includes the number of pills to take and at what time of day. The dispenser should run with a scheduler and should dispense dose within a minute (60 sec) of inputted time. The dosage must be outputted based on application specifications 99% of the time.
2. Track whether the pills have been taken through application interface of caregiver. User's profile should show whether or not the medication was retrieved and receive an update on status from the retrieval site. This is maintained through a weight sensor capable of precision needed for mg weight of pills.
3. Configure dispenser remotely from mobile application by allowing caregiver to input the type of medication put into the dispenser, the number of pills to take, and at what time the pills should be dispensed. There will also be an update when the pills must be refilled on the application so the caregiver can unlock the dispenser on the app and then refill the medication.

2 Design

2.1 Physical Design

The design of our pill dispenser uses the pill counting design from modern machines to output pills based on a specified amount. There are two pill dispensing plates to allow for two separate types of medication, but both output to the same cup at the bottom of the machine. The rotating discs use the motors to turn when prompted and the pill size corridor control ensures that pills leave in a line so only one pill passes the IR sensor at a time. This allows the sensor to send the data to the control unit to track the number of pills dispensed. The weight sensor below the cup is used to track whether the pills have been taken from the dispenser or not and can be updated on the mobile application. On the front door of the dispenser, there is the EM "Fail-Secure" Lock to deter patients from breaking into the machine. The small door at the bottom allows the user to take the cup and the pills from it. The WiFi unit and control unit are placed in the bottom at the back in order to have as much space as necessary. Finally, the mobile application connects to the mechanism using the WiFi unit and can help control the machine with when to dispense the pill, if the pill has been taken, or if it is necessary to refill.

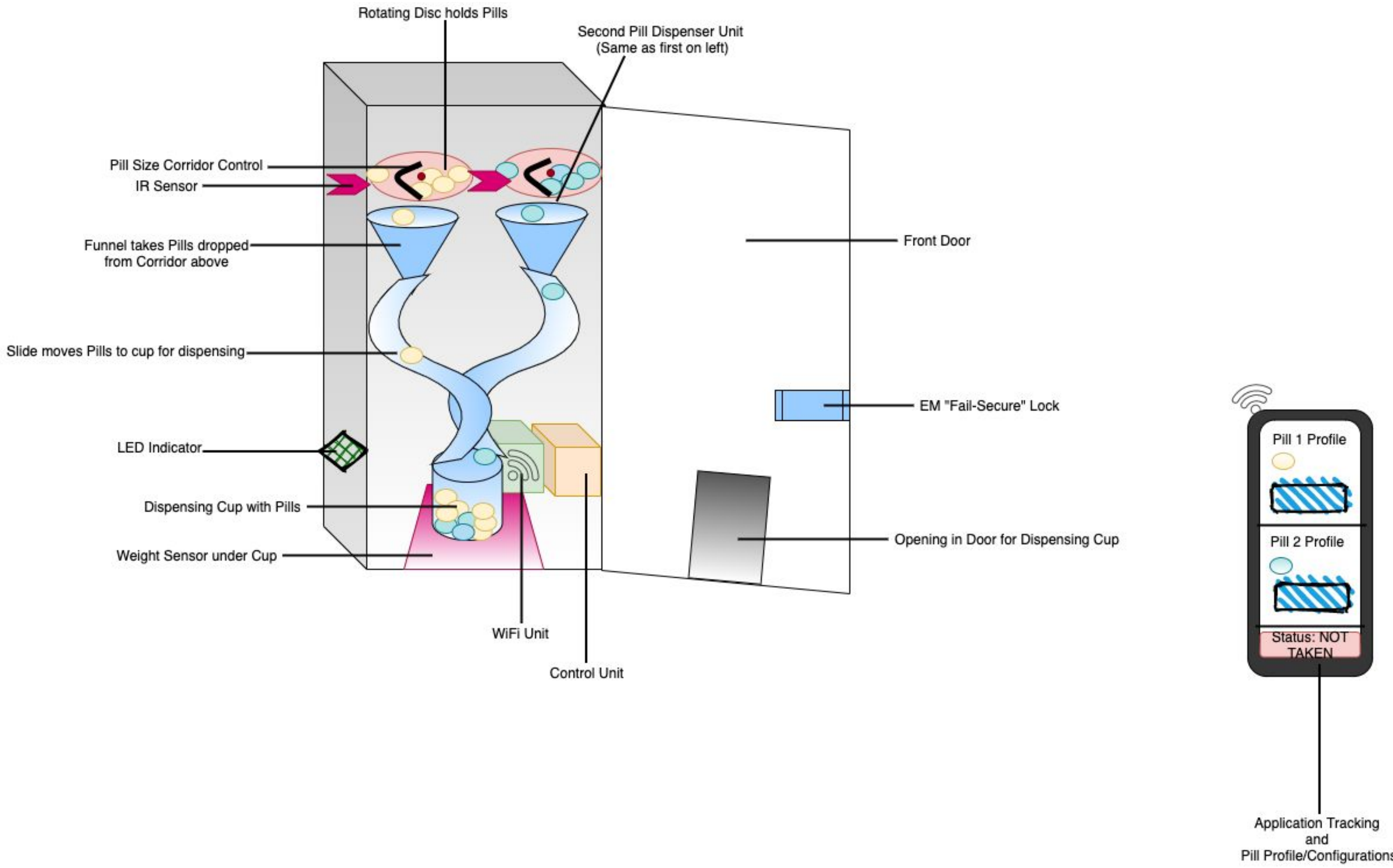

Figure 2.1.
Physical Diagram

2.2 Block Diagram

This pill dispenser requires seven sections for correct operation: power supply, microcontroller, WiFi module that connects to a server and an application, safety mechanism, sensors, motors, and an indication system. The power supply ensures that the microcontroller, sensors, lock, WiFi module, motors, LEDs, and speaker can be powered with the proper 5V. The control unit contains a microcontroller to interface with the sensors, motors, LEDs, speaker, and WiFi module. Thus allowing the microcontroller to dictate when each item's data will be used, or when it should be deployed. A WiFi module connects this control unit to a standard IEEE 802.11b/g/n WiFi network. This is so that the connected server module can interface between the mobile application and the microcontroller. The safety mechanism is connected to the microcontroller to be locked or unlocked by the microcontroller. The sensors and motors are in order to dispense a pill and are connected to the microcontroller so a specific time to run can be configured. Finally, the indication system, consisting of LEDs and a speaker, is also connected to the microcontroller to change which LED is lit and when the speaker will output noise to alert the user.

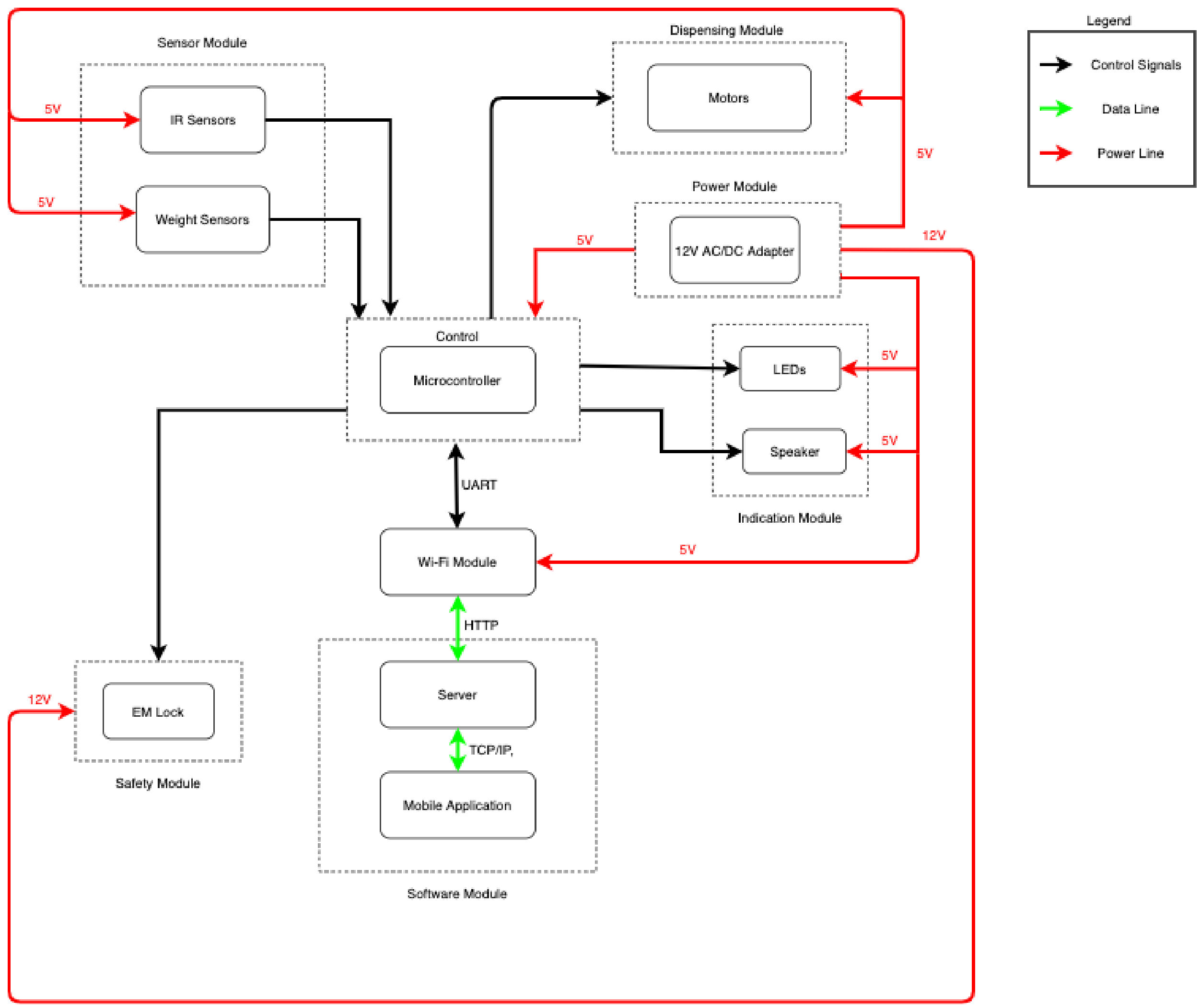

Figure 2.2.
Block Diagram

2.2.1 Power Module

A power supply is required to keep the microcontroller, sensors, motors, LEDs, speaker, EM Lock, and WiFi module working.

2.2.1.1 12V AC/DC Adapter

Power supply will be connected to the microcontroller, regulated for 5V for most of the other modules and then distributed where necessary. For the EM Lock, we will need to take the power from the microcontroller, but not regulated for 5V, instead it should stay at the 12V. The power will be plugged into an outlet for easy access and less replacement, therefore we need to convert the high power output from the outlet to the 12V that our system needs.

Requirement: Must output 10.5VDC ± 1.5 VDC and 2.95A ± 0.05A at an error range of 0 - 25%.

2.2.2 Control

A control unit manages all the separate parts of the dispenser and allows them to react or deploy given specific requirements. The motor, sensors, EM lock, LEDs, and speaker need to be run at specific times to ensure that a pill is dispensed correctly and at the right time.

2.2.2.1 Microcontroller

The microcontroller, chosen to be a PIC32, handles memory allocation for the cache. It communicates with the WiFi chip via UART and reads the SD card cache through SPI (Serial Peripheral Interface).

Requirement 1: The microcontroller must be able to communicate over UART at speeds greater than 4.5Mbps.
Requirement 2: Must sink or source 10mA on each of two GPIOs at 3.3V +/- 5%.

2.2.3 Dispensing Module

The dispensing module consists of the motors used to control the plates that allow only a few pills into the limited channel and to lessen the flow of pills outputted. This ensures that only the correct number of pills are dispensed.

2.2.3.1 Motors

The motor is a servo motor that will control the plate that holds a maximum of 20 pills at a time. This will interact with the microcontroller to know when to turn on to dispense the pill.

Requirement 1: Must operate at 5.0VDC ± 0.2VDC.
Requirement 2: Must rotate 360° for a minimum of 0.07sec ± 0.01sec/60°.

2.2.4 Sensor Module

The sensor module is made up of IR sensor(s) and a FX292X-100A-0100-L load sensor which keep track of how many pills leave the plate at the top and whether the pills are actually removed from the bottom.

2.2.4.1 IR Sensors

The IR sensors are located where the pill exits the rotating plate to keep track of the number of pills that exit to the cup. This is to ensure only the prescribed number of pills are dispensed.

Requirement 1: Must operate at 4.1VDC ± 1.4VDC.
Requirement 2: Must be able to detect a pill from a minimum of 5mm away to a maximum of 40mm away.

2.2.4.2 Weight Sensors

The FX292X-100A-0100-L load sensor is located below the cup where the pills will be dispensed to. This sensor detects the weight and therefore can tell the difference between weight when the pill is dispensed and once it has been removed by the user.

Requirement 1: Must operate at 5VDC ± 0.25 VDC.
Requirement 2: Must be able to differentiate between when the cup has no pills and when it does have pills (through difference of weight measurements).

2.2.5 Safety Module

The safety module is meant to deter overdose of pills or tampering with the system.

2.2.5.1 EM Lock

The 1528-1191-ND EM Lock will be used to ensure that the front of the mechanism is locked at all times unless specified to be unlocked through the app. The microcontroller will maintain control over the lock.

Requirement: To remain locked unless specified by microcontroller by means of application. In case of a power removal, the EM Lock should remain in its natural state (locked). Unlocking requires 10.5 VDC ± 1.5 VDC to shift solenoid.

2.2.6 WiFi Module

Data from the control module (microcontroller) is sent via UART to be accessed on a WiFi network. A WiFi SoC (System-on-a-Chip) operates off SPI flash program memory and uses an antenna for both receiving and transmitting.

2.2.6.1 WiFi IC

We have chosen our WiFi IC, the ESP8266, with cost in mind. This chip includes a 32-bit microcontroller and WiFi transceiver. This was chosen since it allows for easy information relay to and from a local server created from the WiFi module. It operates at 160MHz (overclock) and has data input communication with the PIC32 microcontroller via UART.

Requirement 1: The WiFi IC must be able to communicate over IEEE 802.11b/g/n at >100kbps with a 50 nominal RF connection.
Requirement 2: It must be able to communicate over UART.

2.2.7 Software Module

Data from the WiFi IC is sent to the software module through the server. The PIC32 with the microcontroller is able to communicate to the server that will receive and send the data to the application.

2.2.7.1 Server

The server design will consist of a microcontroller, a cellular receiver, and a WiFi dongle. The main function of the server is to send and receive data to/from the mobile application.

Requirement 1: Must be able to establish port connection for host-client transmission of data from microcontroller to application.
Requirement 2: Use POST and GET requests for transferring data, interface between microcontroller and establish wifi connection.

2.2.7.2 Mobile Application

The main function of the application is to allow the caregiver to put in details of the pill intake and keep track of when the pill has been taken and when to refill. This will serve as the main interface for any adjustments to the pill dispensing.

Requirement 1: Must be able to connect to the server by WiFi and access updates from the server.
Requirement 2: Must be able to relay updates from the application to the server.
Requirement 3: Must allow the caregiver to successfully unlock the machine for medication refill and be updated on the status of pill dosage and dispensing.
Requirement 4: Should allow the caregiver to input prescription details to change the mechanical environment such as dispensing the appropriate medication and locking and unlocking the dispenser to add in more medication.

2.3 Risk Analysis

The highest risk in this project is the ability to accurately dispense the correct number of pills at the designated time. This is difficult because the mechanics of the disc holding the pills must work to the specification we have set and the IR sensor must accurately and quickly count the pills. The time between the IR sensor detecting the pill and the microcontroller stopping the motor of the disc must be close to instantaneous to not allow errant pills from dispensing. This would cause too much medication to be dispensed which is what we are trying to avoid.

Another risk factor is the WiFi module and the Mobile Application. If we are able to successfully dispense a pill, there might still be an issue with connecting to the application, adding updates and allowing the caregiver to access information about the dispenser. The mobile application needs to be fully functional in order to add value to the project, but if the mechanics of the dispenser take too much time, the application may only be partially functional. This is especially true since the WiFi module must connect to the server and also be able to relay information back and forth between the microcontroller and the server.

The risk of the wrong amount of pills dispensed or false information relayed from the interface could cause overdose or underdose. This type of mismanagement could be fatal and is also a large risk we are undertaking.

As we are currently in a pandemic, we need a contingency plan. Our plan is to focus more on the software part of the project where we can track whether the pill has been taken and whether to refill. In addition to those functionalities, we will add tracking of the number of pills and notifying the caregiver if and when the medication is taken.

3 Safety and Ethics

There are a few potential safety hazards with our project. This is mainly regarding the use of a microcontroller, sensors, motors, EM Lock, and a WiFi module. This is because there could be the issue that the microcontroller stops working or sends wrong information about the amount of pills to dispense. If it is too many pills, overdose can cause fatal or potentially lethal side effects such as internal bleeding, bruising, poisoning, etc. If the sensors and modules overheat, this could negatively affect the medication as pills become ineffective over 86℉ [4].

Another large safety concern is if the outlet adapter does not work properly, it could allow too much amperage and cause a fire or short circuit the system. To safeguard against this, we will thoroughly test the adapter to ensure it works as expected and double check the connections of the subsystems and modules to ensure they are not receiving more current than they should be. This will lessen the likelihood of a fire. To mitigate the possibility of a short circuit, we will have to double check how we connect power and ground to all of our sensors and modules.

We develop this project in firm belief of IEEE Code of Ethics 1.1 “to hold paramount the safety, health, and welfare of the public”[1] at the heart of our project. This solution proposes to accept the growing elderly population and help assuage the inevitable need for more precise caregiver control. Thus, we also consider safety lock features in case of potential abuse of our product by addicts.

We also seek “to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies”[1] by giving control of the drug distribution to medical caregivers instead of engineers. This technology is being developed for health fields in hopes of improving coverage with accessible innovation.

Furthermore, we earnestly acknowledge the use of prior developed technologies in our modeling of the dispensing system as 1.5 states that we must “be honest and realistic in stating claims or estimates based on available data, and to credit properly the contributions of others.”[1] The aforementioned mechanical complexity we model and alter our dispensing system after seeks to make for a safer and more accurate system for patients.

References

[1] Ieee.org, "IEEE IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 29- Feb- 2016].

[2] U. S. C. Bureau, “By 2030, All Baby Boomers Will Be Age 65 or Older,” *The United States Census Bureau*, 18-Aug-2020. [Online]. Available: https://www.census.gov/library/stories/2019/12/by-2030-all-baby-boomers-will-be-age-65-or-older.html. [Accessed: 16-Feb-2021].

[3] “Experience a truly easy, versatile counter: Rx Count Corporation,” *Rx Count*, 02-Feb-2021. [Online]. Available: https://rxcount.com/?gclid=Cj0KCQiAgomBBhDXARIsAFNyUqNoHzUp7Z8ox-7JUDuvFTt4N_WOWLr8zn4_upiGtQFmgwp7R--lq-IaAuruEALw_wcB. [Accessed: 16-Feb-2021].

[4] M. Shomon, “Variations in Temperature May Be Hazardous to Your Drugs,” *Verywell Health*. [Online]. Available: https://www.verywellhealth.com/how-temperature-can-affect-medication-stability-3233264. [Accessed: 16-Feb-2021].