PILLOW: A UNIVERSAL SYSTEM FOR PILL DISPENSING

Team 28
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1. Introduction

1.1 Objective

Every day millions of people abuse their prescribed medicines by either under-dosing or overdosing. Additionally, over-the-counter drugs such as Allegra can be misused because of their side effects. Also, people are prone to forget to take their medicine at the right times and dosages. Over a period of time, this irregularity in taking the medicines can seriously affect one's health. What if we can solve this problem and move a step closer to ensuring perfect health through medicines for everyone everywhere?

Our solution is to build a two-module system. Most critical to the system is a universal pad (the 'Pill Scale') that attaches to the bottom of an existing pill bottle and detects how much of the medication is removed once the bottle is accessed. This pad is powered by batteries and connected, by Bluetooth, to a second module, an outlet-powered hub (the 'Pill Hub'). This hub allows the system to be connected to Wifi without increasing the size of the hub. This allows us to construct an application for the users, and their physicians, to update the system with relevant information such as pill weight, dosage, and scheduled times to medicate. Altogether, this system intends to be the assurance that even the most forgetful of users will get the exact amount of medication they need.

1.2 Background

Other attempts to solve this problem have been focused on replacing the actual pill bottles with some sort of automatic dispenser. Because of the (often) motorized components involved, these products can be much larger, more power-hungry, and more expensive than our solution. And the cost is the most pressing concern with these solutions - current dispensers on the market start at hundreds of dollars [1]. The components going into our system are inexpensive and will give the users access to an effective and affordable solution to over- or under-dosing.

Additionally, the data collected from these pill bottles can be integrated with healthcare metrics and at the same time be monitored by the patient's doctor either through a mobile app or website. It can also be used by pharmacies for automatic refills and scheduled delivery of the medicine. This software element works well with the system's hardware, extending its functionality to solve this problem.

1.3 High-level requirements list

i. Pill Count: The 'Pill Scale' will count the number of times a medicine is taken and at what hours
ii. Reminders: Whether overdose or underdose, the 'Pill Hub' will remind the user in a routine manner.
iii. Analytics: User's activity will be monitored and shared through an app (to both the user and doctor). The activity can be quantified by making meaningful graphs.

2. Design and Functional Overview

We will be using a 'Pill Hub' which has Wifi and Bluetooth modules. The hub will be connected via Bluetooth to multiple small 'Pill Scale'(s). The 'Pill Scale' will have a universal design such that it can be attached to the base of any regular bottle or dispenser available these days. The 'Pill Scale' will have a weight, gyroscope sensor and Bluetooth module which gives regular feedback to the 'Pill Hub'. The hub will be connected to the home wifi to easily communicate with the website/mobile app for the product and provide valuable metrics and reminders to patients, doctors and dispensaries. The above modules will be connected using a self-designed app microcontroller.

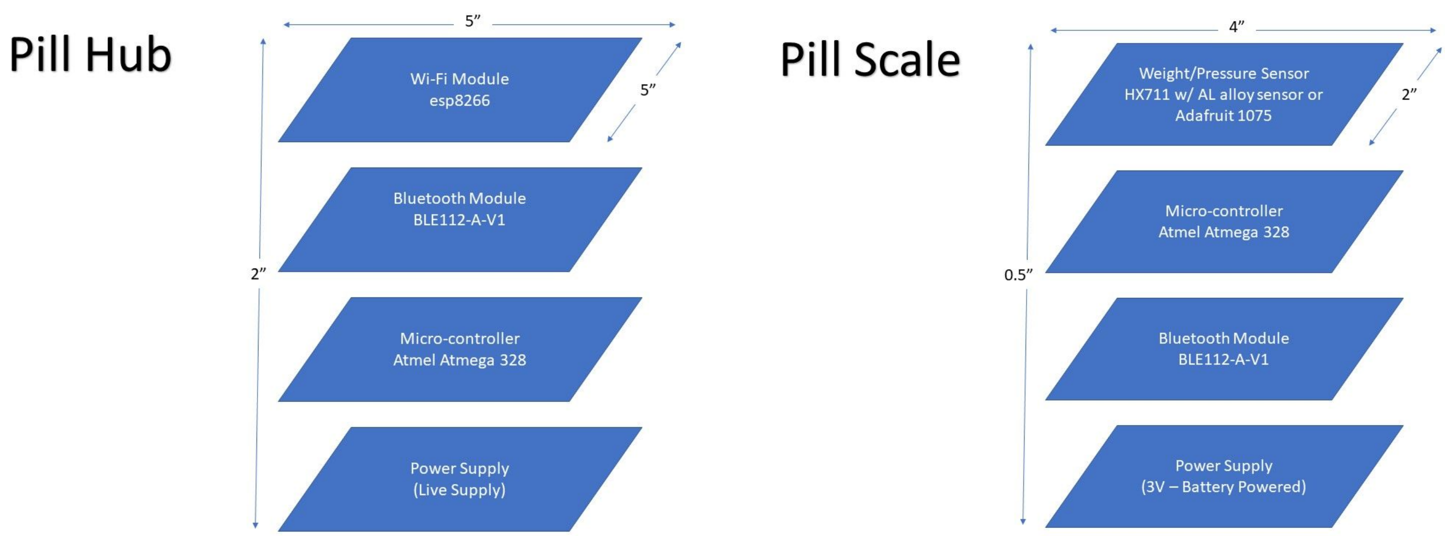

Figure 1. Physical Design of Pill Hub and Scale

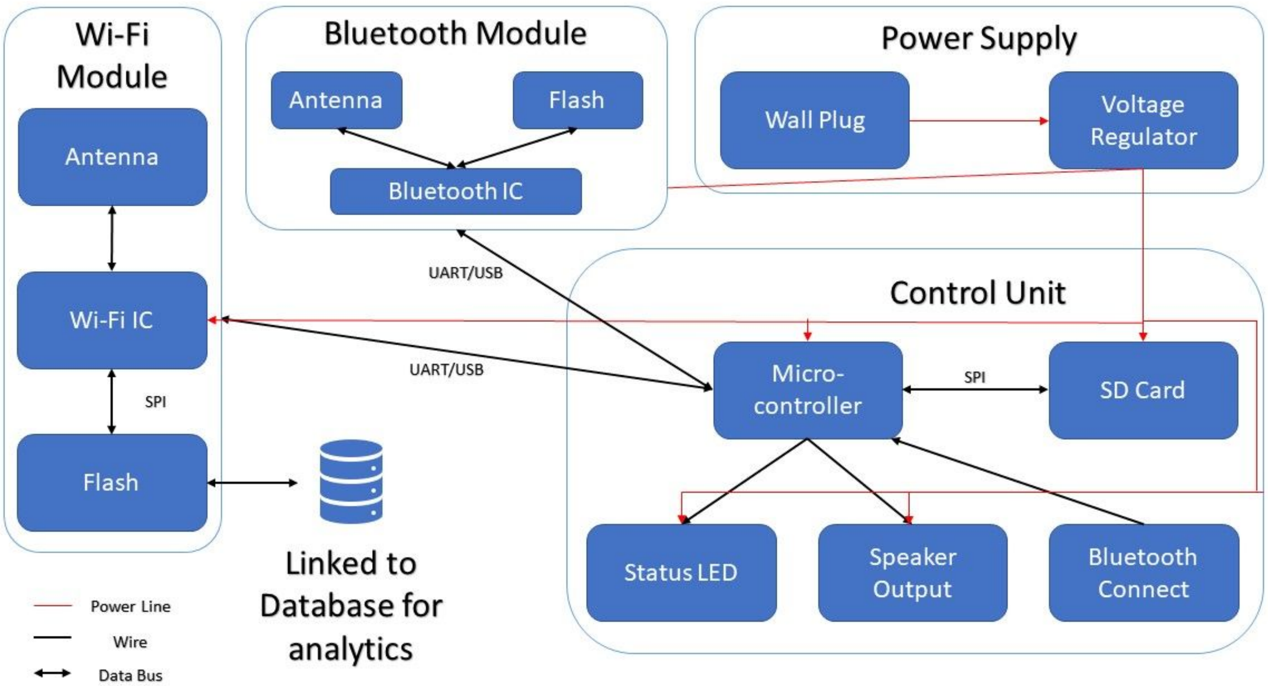

Figure 2. Block diagram for Pill Hub

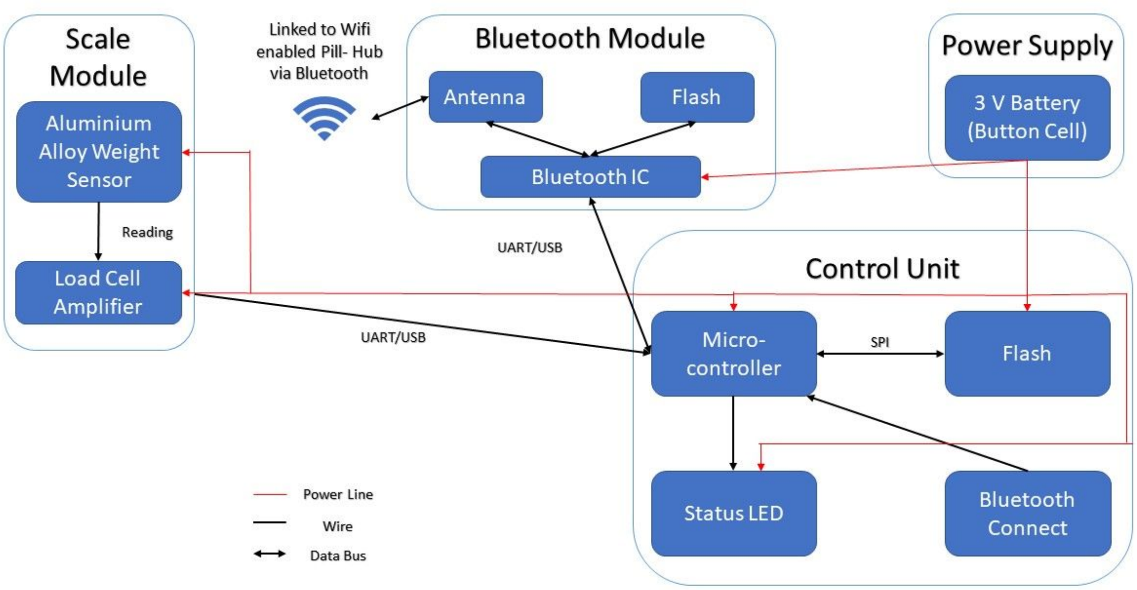

Figure 3. Block diagram for Pill Scale

2.1 Power Supply

A power supply is required to keep the Pill Scale communicating with the Pill Hub. Power from a wall plug will keep the Pill Hub connected to the database for analytics.

2.1.1 Wall Plug

Connected to an AC power supply or outlet at home. Input Voltage: 100-240V ~ 50/60Hz 500mA

2.1.2 Voltage Regulator

The integrated circuit provides the required 3V to the Bluetooth and Wi-Fi module. This chip must also be able to handle the maximum input from the battery.

2.1.3 3V Battery

The Lithium Ion battery must be able to keep the Pill Scale circuit continuously powered especially in the morning and evening when the device will primarily be in use.

2.2 Control Unit

A control unit prepares data to be sent over UART to the Wi-Fi, Bluetooth, and Scale module and it manages the flash storage. The microcontroller controls the SD card and provides a simple user interface with a status LED and speaker. The microcontroller we chose is the Atmel Atmega 328.

2.2.1 Microcontroller

The microcontroller communicates with the Wi-Fi, Bluetooth, and Scale chip via UART and reads the SD card cache via SPI.

2.2.2 SD Card

The microSD card will serve as cache and save data in case of losing connectivity with home Wi-Fi.

2.2.3 Bluetooth Connect

The Bluetooth connection will allow users to connect to their Pill Hub and pair with the device for setup.

2.2.4 Status LED

The status LED will display to the user whether the Pill Hub and Pill Scale are connected to the Wi-Fi and Scale modules respectively.

2.2.5 Speaker Output

Speaker will be able to give a scheduled reminder to the user about his or her medicine.

2.3 Bluetooth Module

Data from the control module is sent via UART to be accessed on a Bluetooth network.

2.3.1 Antenna and Bluetooth IC

The Bluetooth IC, the BLE112-A-V1, allows for low energy features which makes it ideal for the Pill Scale and Hub as the chip only consumes 400nA in its lowest sleep mode and will wake up in a few hundred microseconds.

2.3.2 Flash

The Flash holds the program memory for the Bluetooth IC. Currently, we do not know our programs size for the microcontroller, but we will prototype a size less than 1MB.

2.4 Scale Module

2.4.1 Aluminum Alloy Weight Sensor

We will use 0-100 g electronic scale aluminium alloy weight sensor.

2.4.2 Load Cell Amplifier

The signal sent from the weight sensor needs to be amplified in order to be processed by the microcontroller. SparkFun load cell amplifier (HX711

- https://bit.ly/2nOrBYq) can be used for this purpose. This will give us a mg precision.

2.5 Wi-Fi Module

Data from the control module is sent via UART to be accessed on a Wi-Fi network.

2.5.1 Antenna and Wi-Fi IC

The Wi-Fi IC, the ESP8266, is a self-contained SOC with integrated TCP/IP that gives our microcontroller access to the users Wi-Fi network.

2.5.3 Flash

The Flash holds the program memory for the Wi-Fi IC. Currently, we do not know our programs size for the microcontroller, but we will prototype a size less than 1MB.

2.6 Risk Analysis

The most important component of the project is the pressure sensor. Making sure that it operates correctly is central to the operation of the system at large. But further, a malfunctioning scale can have grave consequences - if our scale is inaccurate, then the dosage given will not be correct. This would negate the whole purpose of this system, opening up the patient to the possibility of under- or over-dosing. The strategy involved to avoid this issue is twofold: First, the manufacturer of the pressure sensor we plan on using has an extensive implementation guide [2], which we need to follow exactly in order to ensure that our sensor is operating correctly. Second is simply rigorous testing and calibration. Since we are only making one of these products, we can make sure that this pressure sensor is working exactly within our specifications without having to make sure that the specifications transfer correctly to other pressure sensors.

3. Ethics and Safety

3.1 Safety

There are three general safety concerns for this project. The most pressing concern is, as mentioned above, the accuracy of the scale module. If the scale doesn’t work properly, then the system could push the user to either under- or over-dose, nullifying any good intentions we have with constructing this system. The health of the user is the central tenet of this whole project, so it is certainly a safety concern if we can’t be confident that the scale is being accurate.

Also of concern for this project is the network connectivity. Any connection can be finicky, so we can’t completely rely on the system to be connected at all times. Like the accuracy of the scale, the safety of our users is thrown out of the window if the system is unsure about the right dosage. For this reason, the important information (like pill weight and recommended dosage) should be stored on the hardware for offline use.

And as with any project involving electrical components, exposure to electricity is a safety concern. Luckily the modules we are working with require a relatively tiny voltage to operate, around 3 to 7 volts. Still, with the scale module being connected to a battery and the hub connected to the outlet, those power sources could potentially become dangerous with a wiring mishap. In order to ensure the safety of ourselves and the eventual end user, we will be following the guidelines given by the university for electrical safety [3].

3.2 Ethics

Ethically, the most obvious concern with our system is that we are dealing with medical data from our users. We are therefore making ourselves responsible for the health of our users. Both the IEEE [4] and ACM [5] codes of ethics emphasize doing no harm (numbers 9 and 1.2, respectively). In addition, in order to remain compliant with the government’s HIPAA Privacy Rules [6] (and 1.6 “Respect Privacy” from ACM’s ethical code), we need to ensure that the medical information connected to our users is kept confidential, while still allowing the user the ability to share their information with physicians, caregivers, or pharmacists. Making sure that a user’s medical information is under complete control of the individual is tantamount to us making sure that this system follows ethical and legal rules.

References

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[5] “The Code Affirms an Obligation of Computing Professionals to Use Their Skills for the Benefit of Society.” *Association for Computing Machinery*, www.acm.org/code-of-ethics.

[6] HHS Office of the Secretary, Office for Civil Rights, and OCR. “Privacy.” *HHS.gov*, US Department of Health and Human Services, 16 Apr. 2015, www.hhs.gov/hipaa/for-professionals/privacy/index.html.