Medicine Dispenser High Level Design Document

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1 Introduction

As people live longer, people have the opportunity to know their grandparents and even great grandparents longer than they have before. Many have the experience of caring for their aging relatives which can be challenging due to the effects that age has on the body. One such experience is with the medication that is often prescribed to better help individuals combat the effects of age. In fact, 66% of US adults are on prescription medication (Health Policy Institute). A family member or caretaker may be able to sort the medication for the parent, grandparent, or great grandparent, but they cannot be with them at all times of the day to ensure they are taking the medication that helps them. In fact, in many cases, older parents, grandparents, or great grandparents want to continue their independent lives without feeling that they are being monitored. Individuals with other disabilities such as ADHD can also benefit from a system designed to increase consistency of medications taken. In this design project, we are seeking to support continued independence of individuals as well as increased adherence to medication prescriptions. In such a fast-paced world, the simple task of complying to a medication schedule can become difficult with numerous responsibilities and tasks. This design project would tackle this problem by developing an innovative medication dispensing system with personalized reminders.

2 Problem Statement and Proposed Solution

Today's world is becoming increasingly medicated. This is not unexpected as research finds new ways to treat and cure diseases and the expected lifespan continues to increase. People are also more willing to use medication to treat an increasing number of illnesses both physical and mental. In an increasingly medicated world, where the population continues to age, there are many who need to consistently take those medications for them to be effective. It is important that medication is taken regularly and on time. This is important because the primary factor of medicine effectiveness is consistency. If the medication is not taken correctly in the correct dosage it will not perform the function it was intended. Medication is prescribed to be taken repeatedly at intervals when the effectiveness begins to wane. Many of these medications are lifelong prescriptions for chronic conditions. While many individuals may be able to get into a habit of taking their medication on time, there will be cases where they will forget. This is a particular concern with aging populations which have a stronger propensity to develop memory related illnesses.

Our solution is to create a system which reminds the patient when to take which medications. We are assuming that a capable caretaker will be incharge of the initial sorting of the medications into the appropriate days and times within the pill container. The caretaker will also be able to input the prescription information so that the system will then know when and how to dispense the medications as well as any additional relevant information regarding the medication. It will have two main types of reminders which can be customized for the patient: in-home environment reminders and phone reminders. The system will also connect to wifi so that it will have a real time clock which adjusts with timezones and daylight savings time. There will be a sensor in the tray which will send out additional reminders if the medications have not been taken within a set amount of time.

3 System Requirements

- Constant Power
- User Interface for Prescription Input and Reminder Overrides
- Ability to Adjust Basic Settings including Prescriptions
- Multiple Repetitive Reminder Functions
- Dispense Medicine On Time
- Show Drug Reminder Information at Time of Medicine Intake
- Timely End of Reminders Following Medicine Intake

To solve the problem discussed in the previous section, our system needs to meet a few requirements on power, user interfaces, set up, and general functionality. The first requirement is the power requirement. Our system needs to be able to have constant power to ensure that no medication dispenses or reminders are missed. This is true for both the main system as well as the auxiliary systems.

The system also needs to have several interfaces for inputting settings preferences and prescription information. This includes the users ability to see appropriate information when taking medication such as if they are to eat with the medication. This also includes the ability to override the reminders when they take the medication in the case there is an error in the sensor reading.

Upon the set up of the system there are several requirements that need to be met. The system needs to be able to connect to an external interface in which the caretaker or individual can input their prescription needs. The device needs to be able to adjust multiple settings for users comfort in use. For example, if the individual wants to disable the auditory reminders or increase or lower the volume. Other examples might include visual reminder brightness, reminder frequency, and type.

The system also needs to have a variety of reminder types that are repetitive in the case that the user forgets. This system is specifically designed to encourage consistent on time intake of medication so there should be appropriate reminders for all user needs. Some examples include auditory, visual, and phone reminders. These reminders also need to be available in multiple locations in the case that the user is not near the primary device at the time of medication dispensing. This encourages the need for auxiliary reminder systems. The system also needs to give the user any additional information regarding the medication such as if it is required to be taken with food or without food.

The primary function of this system is to dispense the medication on time which necessitates the need for the system to know what time it is and what day it is. The system should also contain a failsafe to not dispense medication if there is leftover medication in the tray so the user does not take incorrect medications. In response to the need to not dispense medication if there is still medication in the tray, the system should sense if there is leftover medication. This serves the dual function of meeting the requirements that it check if the medication has been taken and continue the reminders or terminate the reminders accordingly.

4 System Block Diagram

4.1 Overall System:

The overall system is designed to seamlessly integrate multiple subsystems including the housing and mechanical system, PCB interface, software interface, and auxiliary reminder system. The housing and mechanical system, driven by motors and controlled by the PCB, facilitates accurate medication dispensing through a conveyor system, pad sensor, display, and speaker. The PCB, acting as the central nervous system, orchestrates communication between various hardware components, including the main microcontroller (ESP32-C3), power, medicine pressure sensor, bluetooth module, motor control, speakers, and the display. The software interface, developed using Visual Studio Code, controls the main and auxiliary devices, ensuring a unified control interface, real-time clock functionality, phone reminders, and app/website input and settings. The auxiliary reminder system extends reminders through visual (LEDs) and audio (bluetooth speakers) components. Overall, these subsystems collaboratively create a comprehensive medication dispensing solution, promoting adherence, enhancing user well-being, and providing a user-friendly experience.

4.2 Housing and Mechanical System and Interface Requirements:

4.2.1.1 Conveyer

The medicine containers will be individual boxes with a loose hinged lid. There will need to be seven boxes on each conveyer, one for each day of the week, and three conveyors for taking medication three times a day. The conveyor will activate tipping the desired box over the edge and dumping the medication into the funnel.

4.2.1.2 Motors

The motors will control the conveyor belts, they will need to be controlled so that only the desired boxes get tipped over dispensing the medication.

4.2.1.3 3D printing housing (funnel)

The housing will need to have several features. A funnel wide enough that all three conveyor belts tip over into it. The tube or slide at the bottom of the funnel will need to be as smooth as possible so that no pill gets stuck inside the housing. The housing itself will need to have both the pill track and the display as well as all the wires managed inside the housing so that it is unobtrusive to the user.

4.2.1.4 Pad sensor

The sensor will function to make sure that the medication was dispensed successfully and as a method to be sure that the patient took the medications.

4.2.1.5 Display

The main display which will be directly above the dispenser tray will show several different pieces of information. When medication is dispensed it will show reminders of instructions that go along with the medications, an example of this is whether they need to eat with the medication. After the medication is successfully taken the display will switch to showing when the next medication needs to be taken. There will be a digital clock on the display at all times.

4.2.1.6 Speaker

The speakers will be the primary method of reminding the patient to take their medications. They will be in several locations throughout the home and will announce that it is time to take their medication. The sound will need to be a recording of speech telling them to take their medication rather than a typical alarm sound so that the patient cannot get confused by a beeping sound.

4.3 PCB and Interface Requirements:

4.3.1.1 Power Interface:

The subsystem requires an input voltage range within specified limits and stipulates the necessary current requirements. Additionally, voltage regulation mechanisms must be implemented to ensure stable operation. The board will employ an USB-C port for power and connection.

4.3.1.2 Medicine Sensor Interface:

The medicine sensor interface is designed to detect if the medicine has been taken. Communication protocols and voltage levels are specified to accurately capture and process information from the medicine sensor. The sensor should have a wired connection to the pins of the board since it is in close proximity.

4.3.1.3 Bluetooth Interface:

For the Bluetooth interface, the subsystem selects an appropriate Bluetooth module or chipset and defines the communication protocol (such as UART or SPI). Considerations are made for antenna placement to optimize Bluetooth signal reception.

4.3.1.4 Motor Control Interface:

The motor control interface will consist of the microcontroller controlling the input voltage to the motors, controlling three DC motors independently for the conveyors.

4.3.1.5 Speaker Interface:

In the context of a medicine dispenser, the speaker interface is vital for alerting users. The subsystem will employ a bluetooth speaker that takes input from the weight sensor, or the reminder algorithm, having considerations for volume control, and any required audio signal processing

4.3.1.6 Display Interface:

The display interface, crucial for providing information to users, uses an OLED display with the SPI protocol. Power by the board, and connector types are specified to seamlessly integrate the display into the dispenser.

4.4 Software and Interface Requirements:

4.4.1.1 Control for Main System Interface

This will include developing a centralized control system for both the main device and auxiliary systems and designing a unified control interface accessible through the device's GUI and the web-based platform. We will ensure seamless communication between the main system and auxiliary devices through bluetooth, retrieve medical information from the prescription database, and display relevant information, such as dietary instructions, side effects, or specific precautions on the device's interface during the medication intake time. The output audio (speakers) and visual (LEDs) reminders will ensure correct intake time. We will also implement a feedback mechanism, potentially using medicine sensor and/or user confirmation, to signal successful medication intake.

4.4.1.2 Real-Time Clock

This subsystem will utilize the ESP32-C3's capability for accurate real-time clock functionality by implementing POSIX functions for precise time tracking. It will also sync the real-time clock with external time sources, accounting for timezones and daylight savings time changes. A failsafe mechanism will prevent medication dispensing if the current time does not match the scheduled intake time

4.4.1.3 Phone Reminders

This will enable the system to send reminders to users' phones for additional notifications by implementing bluetooth connectivity to communicate with users' smartphones. We will also develop a mobile and/or web application to receive, display, and manage reminders on the user's phone. This will allow users to customize reminder frequencies based on preferences, ensure synchronization of reminders across the main device, phone and auxiliary systems for comprehensive user experience, and automatically terminate all reminders upon confirmation of medication intake.

4.4.1.4 App/Website Input and Settings

This will create a user-friendly application or website for prescription input and settings adjustments by developing a secure and user-friendly web-based platform using HTML, CSS, and Javascript for prescription input, settings customization, and remote management. We will ensure the platform is accessible through standard web browsers and include input forms for prescription details, allowing users to specify medication names, dosages, and intake times. We will develop a database for the user based on the input forms. We will also implement an override option on the device to skip or delay reminders in case of user-specific needs or errors in sensor reading. This will include options for adjusting audio settings, such as volume control, and visual settings, such as reminder brightness and enable the adjustment of specific medication-related settings, such as indications to take with or without food.

4.5 Auxiliary Reminder Systems and Interface Requirements:

4.5.1.1 **Interface with Main**

There would be seamless communication between the auxiliary reminder system and the main device via a bluetooth connection. An effective synchronization mechanism would be implemented to ensure consistency between reminders and status updates between the main system and auxiliary devices.

4.5.1.2 **Visual reminders**

Strategically placed LED’s within the reminder system provides visual cues to the user. This could include color coded visual reminders that would allow the user to differentiate between the urgency level of the medication. This can also be adjusted to change the brightness of these reminders through the main device interface or a web-based platform.

4.5.1.3 **Audio reminders**

Bluetooth speaker integration would establish a reliable connection between the main device and the speakers to deliver audio reminders. This reminder system can also be adjusted so that the volume is fit for the comfort or need of the user.

4.6 Future Enhancement Requirements

4.6.1.1 **Validation**

Integrating a barcode scanning system to validate medications by scanning prescription labels would ensure accuracy and minimize any errors.

4.6.1.2 **Simplified Set Up**

Along with the barcode scanners, the collected information of the scanned prescription would populate a database with the medication details such as dosage and the schedule. Voice commands or other user friendly interfaces could also be used to enhance user convenience for those that may be at a physical disadvantage.

4.6.1.3 Smartwatch Reminders

Extending the reminder system to be compatible with other technologies such as smartwatches would allow users to receive medication reminders directly to their personal devices.

4.6.1.4 Customizable Voice Prompts

Recognizing the diversity of users that may use this, designing an interface for users to easily select their preferred language or voice within the system setting would be beneficial.

4.6.1.5 Self Tracked Reminders

Utilizing boundary technology would also enable the system to detect the user's location and trigger reminders only when they are within a specific area. Room specific reminders can be set based on their daily routines and would minimize disturbances in other areas of the home that may be shared.

5 High Level Design Decisions

5.1 Housing and Mechanical System

Based on the requirements for this section discussed in previous sections, the housing will be primarily 3D printed. It will be a primarily hollow box with a funnel inside that can catch the medicine from the conveyer belt and funnel it to the dispenser tray. The housing will also have a space for the screen. This will be a screw in frame where the screen fits flush and behind which there will be a space for the PCB and wiring. The display will likely be an LED display so that we can get it to be large enough for any user to read. The sensor to determine if the medicine has been taken will likely be an image sensor, infrared sensor, or weight sensor. This will depend on the sensitivity and price of available sensors and is further discussed in the Open Questions section. Finally, the mechanical system will consist of 3 conveyor belts which will move independently by motors at the correct times and will be controlled by the PCB. There will be boxes or cubbies affixed to the conveyor belt which by gravity will be tipped over the funnel of the main housing and the contents will be dumped into the funnel and down into the tray. There will be enough clearance for the box or cubby to eventually go on the underside of the conveyor and back around to be reset for the next week.

5.2 PCB

The PCB subsystem will be powered by an outlet through a USB-C connection in order to provide constant power to the system. The system will work around a ESP32-C3 which can interface through GPIO, I2C, SPI, and UART. The medicine sensor interface will likely be an infrared sensor, but this is discussed more in the Open Questions section. The project will need an infrared sensor which can do basic serial protocols so that it can interface with the ESP32-C3. The ESP32-C3 also has internal bluetooth capabilities so that is another reason to continue to use the ESP32-C3. The motors will be controlled by the PCB having a GPIO connection potentially through a motor driver. The LED display will likely use SPI or I2C which is manageable by the ESP32-C3.

5.3 Software

The software we will use will be written on visual studio code. The ESP32-C3 has capabilities to get the current time through the POSIX functions. This is extremely important to the success of the project is accurate timing so the POSIX functions will need to be tested. The software will also include controls for the main and auxiliary sensors and components. The software subsystem will also include the phone reminders through bluetooth. Finally, the software section will include a website to input the information on the prescriptions and settings preferences. To achieve this we will use html.

5.4 Auxiliary Reminder Systems

5.4.1.1 Interface with main, visual reminders, audio reminders

The auxiliary system will have to interface with the main system through bluetooth primarily. It will also have to receive inputs to turn on visual reminders which will constitute an LED and audio reminders which will be from a speaker. The speaker will have to output voice speaking so it will use a speaker closer to the ones needed for bluetooth from a phone. There are additional unknowns surrounding how to integrate the speaker which is discussed further in the Open Questions section.

6 Open Questions

There are several considerations for this system that still need to be finalized. We need to consider how to incorporate the auxiliary systems and phone functionality, mechanical dispensing system, and sensor for if the medicine has been taken. We are concerned that the extent of the bluetooth we want to perform might be too much for the ESP32-C3 to handle and therefore should consider what other options we have available to us to communicate with the auxiliary systems and phone interface. In addition, the medicine dispensing mechanism is critical to the success of our project and therefore it needs to be consistently successful. We have several ideas for how to accomplish this, one being the conveyor belt system described extensively in this document and another being a rotary option which we would want to explore further. This is an open question because we have not tested any designs yet and therefore do not have a sensor for which will be the best option. The final consideration is what type of sensor to use to determine if the medicine has been taken. A few considerations are a weight sensor, image sensor, or infrared sensor. The weight sensors that we saw on the market are likely not going to be precise enough so we will need to look into how we could use image sensors or infrared sensors to do the same function.

7 Major Component Costs

Components	Cost	Amount
ESP32-C3-WROOM	$10	1
DC Motors	$7 each	3
Conveyor Belts	$10 each	3
Pill Storage Containers	NA	21
SPI LCD Display	$50	1
LED	$5 - $20	5+

Speaker	$20 each	3
Thin-Film Pressure/Force Sensor	<$20	1
Pushbutton	<$10	1

Table I. List of needed components and their respective cost

8 Conclusions

In conclusion, our medication dispensing system provides a unique solution to a large healthcare issue. Through the integration of technology and user-friendly interfaces we can provide a reliable tool that would not only improve the consistency of medication adherence but also provide a lasting positive impact on a patient's well being. Our system ensures a more efficient and accurate dispensing of medication that would reduce the amount of missed doses. The design also caters to a diverse audience enhancing accessibility. Demonstrated features include timely distributed prescriptions, customizable reminder notifications, drug information, caretaker input, and real time tracking of medical adherence would highlight the adaptability and effectiveness in our innovative approach. As this develops, we envision an ongoing trend of transformation in healthcare practices that would become patient-centered care.

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