Multi-Function IoT Button

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1 Introduction

1.1 Objective

The average person's life is far more complex than it was a hundred years ago. In this day and age, people have far more hectic schedules and must keep track of more responsibilities than they would have in the past. People are also more aware of the impact that their lifestyle has on their health. With all these new daily tasks and responsibilities, it has become harder to keep track of everything.

Our goal is to better keep track of these daily objectives by creating small, multi-purpose, IoT-enabled buttons with LCD displays. Each button can be placed in the physical location where the task or goal is to be accomplished to act as both a physical reminder and a way to see if the goal has been met. The button can be set to 3 different modes: Counter (keeps count of button presses, ex. press to record each cup of coffee to monitor caffeine intake), Checklist (timely reminder to perform a task, ex. press to show everyone in household that the dog has been fed), or scripted action (assign task to button, ex. place near bed and press to turn off all lights in home). They would connect to a device via Bluetooth to send and receive data through an iOS application, and to detect if a user is home. Our plan is to have all of features of the button to run on it's own hardware rather than through the connected bluetooth device.

1.2 Background

Software applications already exist to aid in our remembering, including calendars and checklist applications such as Todoist [1]. However, these applications often fail to be flexible in regards to location and changing schedules, only able to send reminders at set times. To take location into account, most applications will at best react to a geofence around an entire building. However, tasks are often forgotten without a physical reminder in the exact location they are to be completed. Even if you remember or are reminded to do something in one room, upon walking into the room containing the task, you may get distracted and forget why you are there due to the “Doorway Effect” [2]. This heavily studied phenomenon explains the common memory loss that occurs upon crossing physical barriers, such as when entering another room or getting into a car.

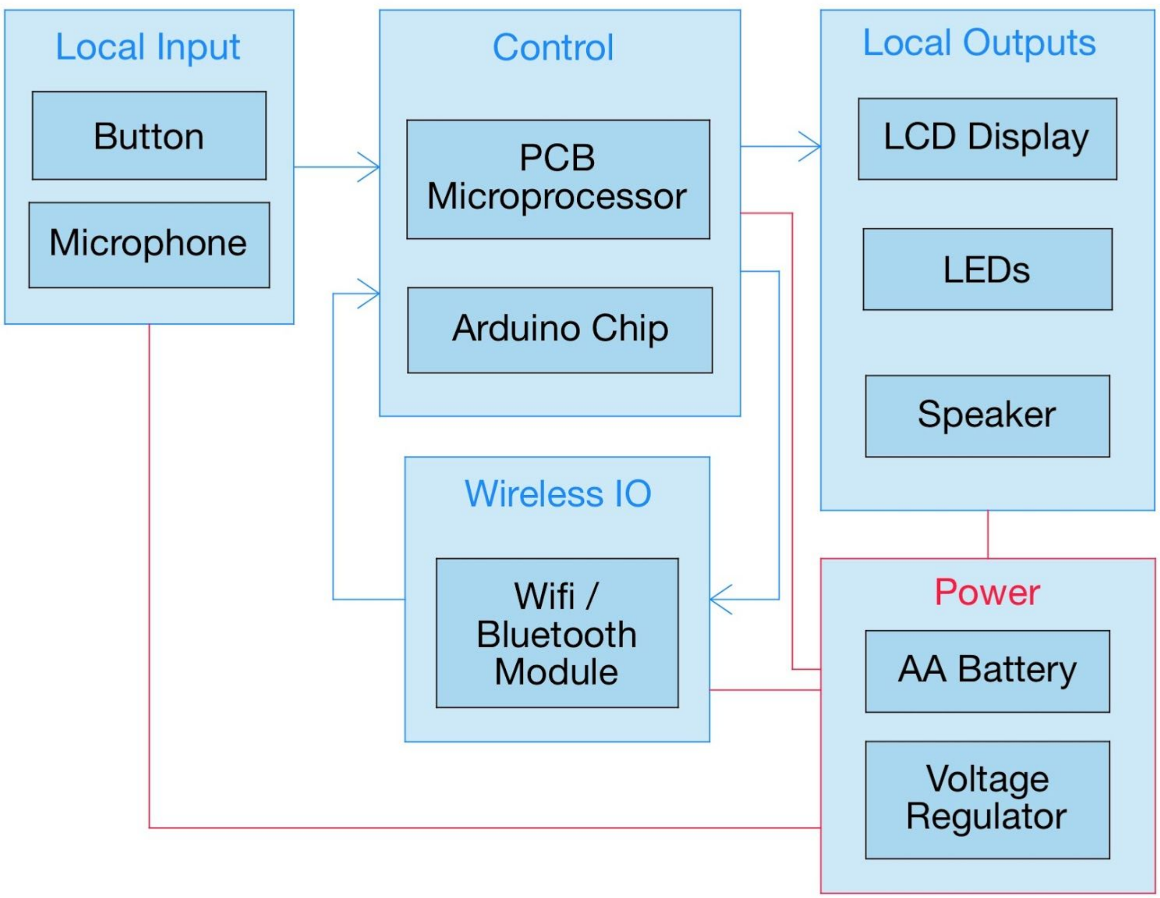
Our button would be an elegant solution to this problem. By putting a button right where the task is to be completed, the button will beep with increasing frequency and intensity as the due time approaches to draw the user into the room to complete the task. This would prevent the doorway effect mentioned above and allow some flexibility in when tasks need to be accomplished. Users could view the data regarding their daily habits collected from the buttons on their smartphones through a bluetooth connection. The buttons could also carry out actions such as sending texts or controlling lights through the smartphone, making them IoT connected. As the inspiration for this project came from the Amazon IoT (Dash) button, we plan for our button to have a similar form factor [3]. The button should also be similarly priced (although the display, microphone, and speaker will add significant cost) and have a comparable battery life.

1.3 High-Level Requirements

- Buttons must be able to connect to an application on the phone or computer wirelessly (through Bluetooth) to allow data collected to be stored on it.
- Buttons must be able to recognize their currently desired function, be able to correctly carry it out independant of all other features (including the connection to the smartphone).
- Buttons must consume as little power as possible so as to prolong battery life, ideally able to last weeks to months.

2 Design

Our project can be divided into five parts: Power, Local Inputs, Local Outputs, Control, and Wireless IO. The power supply (battery-powered) powers the buttons continuously regardless of time of day and should be able to maintain power for weeks to months before requiring changing. The local inputs send the designated data to control to properly handle it. The control then decides the reaction and sends the correct response to local outputs. Our wireless IO of choice (Bluetooth) connects our system to the user device to send and receive data. It allows our buttons to be initialized by an iPhone and detects if the user is away to enter a power-saving mode.



2.1 Power Supply

A power supply is required for each individual button to keep them functioning as long as the user is present. For our buttons, a small battery should suffice to power it in its entirety.

2.1.1 Battery

A standard battery such as a AA or AAA must be able to sufficiently power the button and all its required components.

Requirements:

1. *The battery must supply sufficient voltage and current to the regulator to power all of the blocks.*
2. *The battery must have sufficient capacity to power the device for at least one month.*

2.1.2 Voltage Regulator

The voltage regulator must provide a steady supply of constant voltage to the PCB and other components. It will step up the voltage if necessary

Requirements:

1. *Must provide a constant voltage and prevent spikes/fluctuations*
2. *Must step up/down voltage where required for different components*

2.2 Wireless IO

2.2.1 Bluetooth

A Bluetooth chip within each individual button must be able to communicate effectively with a phone (or whatever other device the user intends to use).

Requirements:

1. *The Bluetooth chip must be able to detect if the user device is within the premises. If not, it must be able to communicate this to the rest of the button to enter a low-power mode.*

2. *If the button detects a user, it must be able to connect to the device to send and receive data.*

2.3 Local Inputs

2.3.1 Button

We intend to adapt from or build on the design of the Amazon dash button. It should register the press from a user, and update relevant information (ex. that the user has taken his/her daily medicine).

Requirements: The button must be able to register user's press and send the corresponding signal to device to update information.

2.3.2 Microphone

The purpose of the microphone is to capture several voice commands; those commands can be uttered by the user under certain circumstances. For example, if the deadline for a task is approaching and the speaker is active, the utterance of the word “stop” should make the speaker stop making noises. The microphone will capture those voice commands, and transfer analog signal to the Arduino Uno or Mega chip, where the analog signal will be converted to digital, and processed for word recognition.

Requirements:

1. *The microphone must be able to accurately capture speech within a 10 foot radius.*
2. *The microphone must be able to transmit captured speech signals to Arduino for processing.*

2.4 Local Outputs

2.4.1 LCD Display

A non-backlit LCD display that must be able to display various pre-programmed instructions (“take medicine”), feedback (“task accomplished, good job!”), etc. corresponding to its current functionality.

Requirements:

1. *The LCD display must be able to display the right message with minimal power consumption.*

2.4.2 LED

A visual LED that must be able to react when time indicated for task completion approaches. Blinks on and off until button is pressed or command is given.

Requirements:

1. *The LED must blink with increasing frequency as checklist due time approaches, or once after a task is completed.*
2. *The LED blinks different colors for different purposes. Red is a warning and green is a confirmation/encouragement.*

2.4.3 Speaker

A speaker that must be able to react when time indicated for task completion approaches. Beeps until button is pressed or command is given.

Requirements:

1. *The speaker must beep with increasing frequency and intensity as checklist due time approaches*
2. *A voice command or long button press must be able to temporarily disable the beeping.*
3. *Beeps with “Encouraging” and “Discouraging” sounds for the counter depending on whether a daily goal was met or a limit was exceeded.*

2.5 Control

2.5.1 PCB Microcontroller

This is the control unit we will design using AutoDesk EAGLE. It will implement one large state machine is used in the operation of the button. The state machine will have three main branches for each mode the button is set to. State transitions will react to button inputs as well as some sort of timekeeping chip on the PCB.

Requirements:

1. *Must be programmable to set the button to a certain mode and label*
2. *Must be able to correctly read the inputs (button press, bluetooth, data from arduino speech processor)*
3. *Must set proper outputs to LCD display, LEDs, Speaker, and iPhone*

2.5.2 Arduino Chip

We intend to utilize the processing powers of an Arduino chip to run word recognition algorithms on extracted features of the audio input. Our main approach is to pre-train the weights and biases of a 3-layered convolutional neural network on a laptop for specific words, and deploy those weights and biases onto Arduino for real-time recognition. Our alternative approaches can be a HMM (Hidden Markov Model) for the words to recognize, or even a simple K-Nearest-Neighbor classifier with a pre-recorded database for feature matching.

Requirements:

1. *The Arduino chip must be able to retrieve sound from the microphone and issue commands to the button.*
2. *The Arduino chip must be able to carry out algorithmic operations on audio input.*

2.6 Risk Analysis

The required bluetooth connection is a significant risk to the completion of this project; our project relies heavily on its success as both detecting and communicating with the user device is essential to the functionality of the buttons. Thus, the bluetooth chips must be able to reach throughout the house so as to be able to reach the device anywhere within the premises as well as detecting when the device leaves so that the buttons are allowed to power down. Not being able to reach the device at any time while it remains within the premises would cause buttons to power down while the user is still present, possibly leading to data not being transmitted in time or, if the user leaves the device somewhere else, pressing a button and the press not being counted.

The microphone voice recognition is a huge risk factor, as the average recognition rate is closely correlated with the Signal-to-Noise-Ratio (SNR). The success of the voice recognition partially depends on the noise level being at a relatively low level, while the voice command is going to be given at times when the speaker is making “discouraging” noises.

3 Ethics and Safety

There are several potential ethical issues with our project.

The buttons would ideally have connection to the internet through their host device, and when something is connected to the internet, it can be hacked. Even though the information of someone’s daily/weekly/monthly routines does not seem as valuable as corporate secrets, that information can still be used against him/her. For example, if someone walks his or her dog at a certain time every day and presses the “walked the dog” button at a certain time, a person with malevolent intentions can know exactly when to expect that someone to come out of their home and harm them, or break into their home. If such a situation was to occur, our project would not be in compliance with the ACM Code of Ethics and Professional Conduct, #1.1: “An essential aim of computing professionals is to minimize negative consequences of computing systems, including threats to health and safety.” [5]. We currently do not have a more desirable plan to protect our future customers from these hacks, other than upgrading the security on their connection, which is beyond the scope of this project.

Dangerous situations could occur when a person become too dependent on the buttons. If the person's ability to recall important tasks in their life is significantly weakened and there is a malfunction in the system, then the person can find himself/herself in confusing and dangerous situations. For example, if someone depends on the "take daily medicine" button too much, then a system malfunction can be deadly - causing them to take too much or not take it at all. Depending on what the medicine is and how important it is to the person's health, the repercussions could be fatal. The above scenario would not be in compliance with the IEEE Code of Ethics, #1: "to accept responsibility in making decisions consistent with the safety, health, and welfare of the public" [4], where health can mean both mental health and physical health. To avoid such situations, we intend to testing our buttons thoroughly before distributing them, and we will issue a caution to not rely too heavily on the buttons and check the collected data on the user's device to our future consumers.

Another potential safety hazard lies in the malfunction of the emergency help application. If we achieve our ultimate IoT goal, and add the utility of sending SOS signals to family members or authorities, from buttons placed throughout the house at key points for an elderly person, we are possibly taking on the responsibility of someone's life. As stated in the ACM Code of Ethics and Professional Conduct #1.2: "One way to avoid unintentional harm is to carefully consider potential impacts on all those affected by decisions made during design and implementation." [5]. As a solution, we can incorporate an "SOS sent" message displayed on the LCD screen after some form of confirmation is received, so that the elderly person can be sure that their signal was indeed sent.

References

[1] Reminders - Todoist. [Online]. Available: https://support.todoist.com/hc/en-us/articles/205348301-Reminders. [Accessed: 06- Feb- 2017].

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[3]"AWS IoT - Amazon web services," Amazon Web Services, 2017. [Online]. Available: https://aws.amazon.com/iot/. [Accessed: 10-Feb- 2017].

[4] Ieee.org, "IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 08- Feb- 2017].

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