Item-Tracking Backpack

Team 66

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Introduction

Problem

A study conducted by Name Bubbles, surveying 400 parents, showed that around 80% of children lose their belongings at school [2]. 52% of the parents answered that the items lost included school supplies, while 36% stated that lunch boxes were among what was lost [2]. For most students, backpacks are their primary means of storing such items. With the ability of backpacks to store many items in various compartments, it is easy for students to lose track of what they have placed in them. It can also become inefficient and time-consuming for students to constantly check whether they have forgotten an item, especially when the number of items they have stored in their backpacks is typically relatively high. Moreover, the different compartments available for students to place their belongings in make it simple for them to become disorganized and lose track of a given item. This issue also results in students occasionally forgetting items at home, forcing parents to need to deliver them in cases where the items are important.

Solution

To solve this issue, our project will aim to provide users with the ability to track the items in their backpacks. RFID will be used to scan tagged items as they are placed and removed from the backpack. Students will be able to make lists of items they are planning on having in the backpack using a mobile application before their commute to school. Separate lists will be made for different compartments to assist users in keeping track of where the items are in the bag. The lists can be modified by adding and removing items, and the status of each item–present, missing, or misplaced–will be displayed for the user to see in real time. The present status will indicate that items are currently in the backpack and in the correct compartment; the missing status will show that an item is not currently in the bag; and the misplaced status will mean that an item is currently in the bag, but in the incorrect compartment. In addition, the time at which a missing item was removed from the bag will be indicated on the application to aid in locating it.

During school hours, many students will not have permission to access mobile phones, so LEDs will be used to allow for quick, but less explicit real-time tracking. Each compartment will have a red LED designated to it. These LEDs will turn on when the user has incorrectly placed an item in the compartment, or if an item is missing from it. The LEDs will turn off after the compartment zipper has been closed, or if they have been active continuously for 30 seconds. A green LED will be used to indicate that all items are present in the backpack and in the correct compartment, indicating that nothing has been forgotten. This LED will similarly turn off after being continuously on for 30 seconds, or after all compartments in the backpack have been closed. The application can then be used after school by parents picking up their children, or by the students themselves, to ensure that nothing is missing or forgotten.

High-level requirements

1. The mobile application shall enable the user to add and remove items to three separate lists, each corresponding to a compartment in the backpack. The user shall be able to track a maximum of at least five items per compartment.
2. The user shall be able to monitor the status of each item—present, missing, misplaced—using the mobile application, and they will be updated at least once every ten seconds. The application shall display what time a missing item was removed from the backpack.
3. The LEDs shall activate within ten seconds of a requirement being met. To conserve power, each red LED shall turn off when its corresponding compartments are closed, and the green LED shall turn off when all compartments are closed. Otherwise, all LEDs shall turn off after being continuously on for 30 seconds.

Design

Visual Aid

As shown below in Figure 1, our project is implemented inside a backpack. It has 3 RFID sensors (The dark red rhombus in the diagram), 3 ambient light sensors (the yellow circles), a PCB (The green rectangle in the diagram), and LED indicators. The sensors and the green and red LED indicators are connected to the PCB using wires. The dark green wires carry power while the orange wires carry data for the RFID tag ID numbers. The purple wires carry the ON/OFF signal responsible for turning the system on and off.

When the backpack is opened, the ambient light sensors will turn the system on. When an item with a tag (shown in brown in the diagram) is placed in one of the compartments of the backpack, the corresponding sensor in the same compartment will read the RFID tag and send the data to the PCB. The microcontroller in the PCB will process the data and light up the green LEDs if all the items are placed inside the backpack or it will light up the red LEDs if there is a missing item. The microcontroller will also send the data to a smartphone app using Bluetooth.

The smartphone app will show the items inside the bag as well as the missing items. It will also add options to register a new item to the list or delete another item.

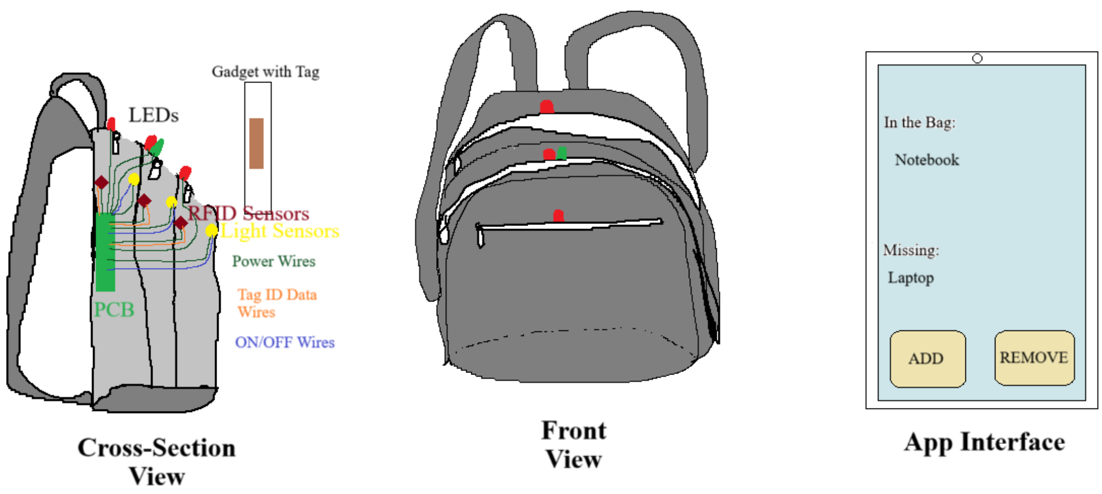

Figure (1): Visual Aid Diagram

Block Diagram

The block diagram is shown in Figure 2. It has four main modules: the power module, the control module, the indication module, and the sensors module. There is also a sixth module which is the

RFID tag module. It is outside the PCB, but it will interact with the RFID readers wirelessly. In addition, the phone app will interact with the microcontroller using Bluetooth 2.4 GHz.

All the power connections use a 3.3 V which is shown in green arrows. The data connections use dotted lines. The wireless connections use dual dashed lines.

The red dotted lines are the ON/OFF signals. They are responsible for turning the entire system on or off. They are obtained from ambient light sensors.

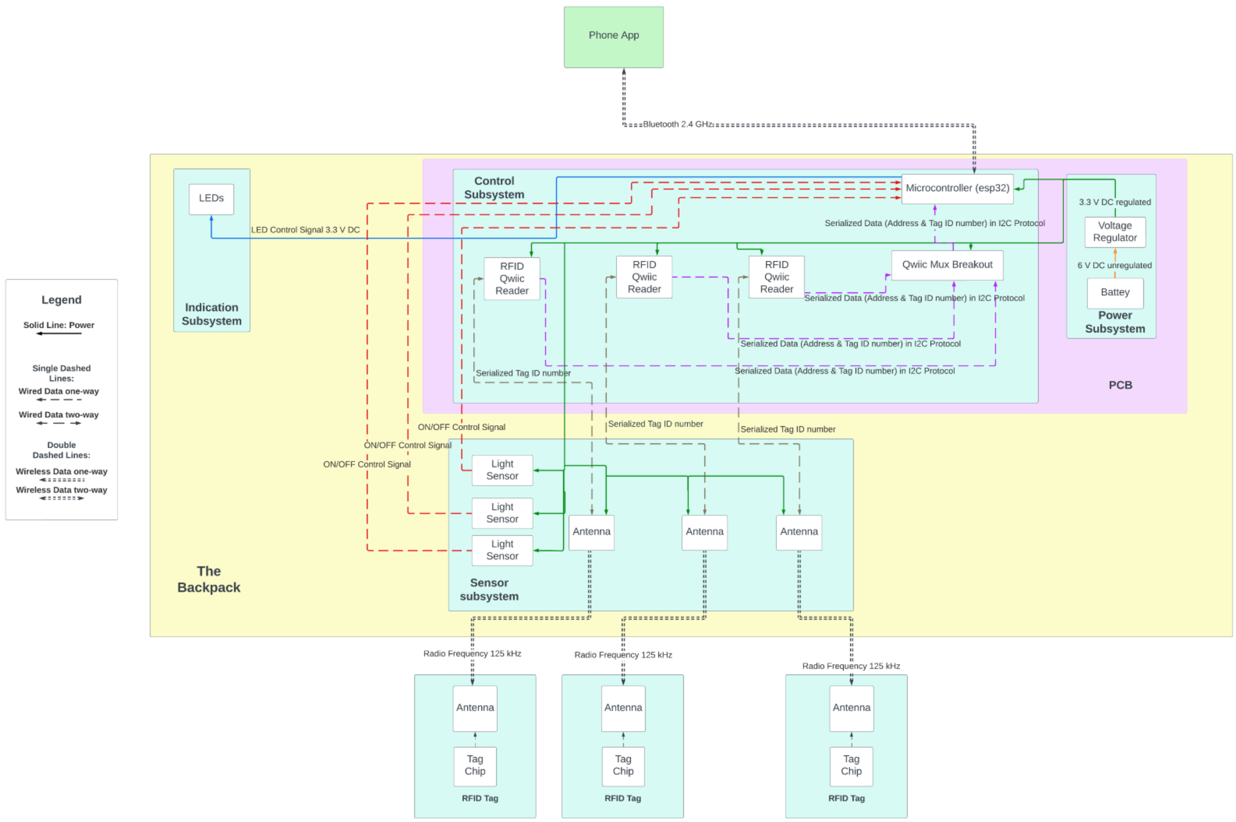

Figure (2): Block Diagram

Subsystem Overview

Sensor Subsystem

The sensor subsystem will be tasked with keeping track of what items are in the backpack and the compartments they are located in. It will also detect changes in the ambient light in each compartment to identify when the compartments have been closed. To carry out the item-tracking functionality, RFID ID-12LA readers, operating at 125 kHz, will be used to detect tagged items as they are placed in and removed from the different backpack compartments. These readers will be connected directly to RFID Qwiic readers, through which the data of scanned tags will be stored. To allow for the detection of changes in ambient light in each compartment, light sensors will be used, which will interface with the microcontroller through I2C. The RFID ID-12LA readers and light sensors will be supplied with 3.3 V from the power subsystem.

Indication Subsystem

The indication subsystem will quickly inform the user about whether all their desired items are in the bag. It will also quickly notify the user if the items in the compartment do not exactly match what was specified in the application. To these ends, a green 5 mm LED will be used to indicate to the user that no items have been forgotten. The LED will activate once all the items listed on the application have been placed in the backpack and in the specified compartments. It will turn off once all compartments have been closed, or once it has been continuously on for 30 seconds. One red 5 mm LED will be assigned to each compartment. The red LEDs will turn on if the items currently in the compartment do not exactly match what is on the application. They will turn off when their corresponding compartment has been closed, or after they have been continuously on for 30 seconds.

User Interface Subsystem

The user interface subsystem will consist of a mobile application to allow the user to track the items in the backpack in real time. The application will also give the user the ability to change the items they wish to track. Furthermore, it will notify the user when an item is placed in the incorrect compartment. To carry out these functions, the application will enable the user to add and remove items from separate lists corresponding to each compartment. The user will have the option of choosing between adding an item that they have previously tracked or inserting a new one. The status of each item—present, missing, or misplaced—will be displayed adjacent to each item and will be updated in real time. Moreover, the time at which a missing item was removed from the backpack will be displayed for the user to see. Bluetooth (2.4 GHz) will allow the mobile application to interface and communicate with the microcontroller.

Power Subsystem

The power subsystem is responsible for delivering 3.3 V DC power to the rest of the subsystems. The power subsystem should supply up to 1000 mA of current. It consists of a battery and an LM317 voltage regulator. The voltage regulator used in this subsystem is a linear voltage regulator (low dropout regulator) with an output voltage of 3.3 V DC. A linear voltage regulator was used instead of a switching regulator because of its low noise output. This is important in this project because the noise might interfere with the sensors. Specifically, the output voltage ripple must be less than 3 mV peak-to-peak to allow the sensor subsystem to work properly. The LEDs in the indicator subsystem will receive power through the microcontroller subsystem, which is powered by the power subsystem. This allows the microcontroller to turn the LEDs on or off.

Control Subsystem

The control subsystem consists of ESP32-S3. It includes Bluetooth which is important for communication with the user interface subsystem. This subsystem will also consist of three RFID Qwiic readers, each connected to a separate RFID ID-12LA reader. The Qwiic readers will track scanned tags by marking and placing them on a stack, and they will relay this information to the microcontroller through I2C. The microcontroller will then transmit the results to the user interface subsystem through Bluetooth at 2.4 GHz. Moreover, the microcontroller will use the information it receives from the Qwiic readers and light sensors to send the appropriate signals to switches for the activation or deactivation of the LEDs. To ensure the microcontroller subsystem can implement these functions, the following Requirements and Verification table will be used.

Subsystem Requirements

Sensor Subsystem

1. The ID-12LA RFID readers must have a read time of no more than two seconds to allow for quick placement and removal of items.
2. Each ID-12LA RFID reader must only read the tags of items placed in and removed from the compartment it is designated to. The ID-12LA readers must not interfere with one another.
3. The light sensors must be able to differentiate between the light intensity of a closed and open backpack.

Indication Subsystem

1. The LEDs must have activation and deactivation times of no more than 10 seconds.
2. The LEDs must be able to remain continuously active for at least 30 seconds.

User Interface Subsystem

1. There must be a clear separation between lists to allow the user to easily differentiate between items in different lists.
2. The status of each item—present, missing, or misplaced—must be displayed adjacent to each item.
3. The status of the items (whether they are present in the backpack) in the lists must be updated at least once every 10 seconds.
4. The hour and minute of items removed from the backpack must be displayed once the status of the item changes from *present* or *misplaced* to *missing*. This time must not be displayed once the item is no longer missing.

Power Subsystem

1. The power subsystem must output 3.3 ± 0.1V DC with very low output noise (less than 3mV peak-to-peak noise) at a maximum output current of 1000 mA.

Control Subsystem

1. The process by which the RFID Qwiic readers acquire the data of a given tag and send this information to the microcontroller must take no more than 10 seconds.
2. The microcontroller must keep track of all the registered RFID tags' IDs. It must also add or remove any of the registered RFID tags' IDs when the user chooses to do so.

3. The microcontroller can interact with a phone app using Bluetooth. This is used to manage the registered RFID tags.
4. The microcontroller must be able to choose which LEDs are powered on.
5. The microcontroller must be able to receive data from the RFID Qwiic reader.

Tolerance Analysis

One possible risk with our design that would prevent the system from being able to successfully track the items placed in the backpack is interference between the RFID ID-12LA readers. Each ID-12LA reader will be attached to one of the two walls of the compartment they will be designated to. It is likely that two of the readers will be attached to adjacent walls, resulting in a minimum distance of approximately 2 cm between them. To ensure that interference does not occur, the penetration depth of the RFID signal must be significantly less than this value. The penetration depth of the RFID signal in a given material can be calculated using the following:

$$\delta = \frac{1}{\sqrt{\pi f \mu \sigma}}$$

Here, *f* is the frequency of the RFID signal, which in this case will be 125 kHz. μ and σ are the permeability and conductivity of the material, respectively. Backpacks are typically made using nylon which has a permeability approximately equal to the permeability of free space μ_0 = 4πE-7 H/m for signals at 125 kHz, and it has a conductivity of 3.8 E-3 S/cm [5]. The resulting penetration depth is as follows:

$$\delta = \frac{1}{\sqrt{\pi(125 \cdot 10^3\ Hz)\left(4\pi \cdot 10^{-7}\ \frac{H}{m}\right)\left(0.38\ \frac{S}{m}\right)}} = 2.309\ m$$

While this may indicate that interference is all but guaranteed, the addition of a few layers of aluminum in the unwanted direction can mitigate this effect. The permeability of aluminum is approximately equal to that of free space, but its conductivity is 3.538E+07 S/m [6]. The penetration depth of a 125 kHz RFID signal in aluminum is therefore as follows:

$$\delta = \frac{1}{\sqrt{\pi(125 \cdot 10^3\ Hz)\left(4\pi \cdot 10^{-7}\ \frac{H}{m}\right)\left(3.538\ \cdot\ 10^7\ \frac{S}{m}\right)}} = 0.239\ m$$

Such a small penetration depth means that a 125 kHz RFID signal can be easily blocked by using a few sheets of aluminum, preventing any interference.

Ethics and Safety

In designing and implementing our project, it is crucial that we adhere to the proper safety and ethical practices. To that end, the IEEE Code of Ethics adopted in June 2020 provides us with important guidelines to be followed. Several of the guidelines mentioned in this code are applicable to our project, addressing aspects of safety and ethics.

1. **Ensuring the safety of the users of this project [1]**

   It is likely that most of the users of this project will not be familiar with the technology implemented. The power subsystem in particular may cause harm to those who unknowingly tamper with it. Therefore, it is of the utmost importance that this subsystem, as well as any other subsystem, be sealed from users, unless exposure is necessary. We plan on having both the microcontroller and power subsystems protected and inaccessible to users.

2. **Safeguarding the privacy of the users of this project [1]**

   One of the major components of this project is the mobile application, which would allow users to control which items they want to track. The application will therefore contain important information about the user, which can possibly be used against them maliciously. It is essential that this information is kept to the user and is not stored externally.

3. **Acknowledging faults and striving to receive feedback [1]**

   With our project originating from an idea, there are many nuances that we may have not yet considered in our initial design. We are approaching the advanced design and implementation of the project with an open mind, aware that some modifications will be inevitable. We are also looking to take advantage of the guidance provided by the Teaching Assistants, Professors, and the Machine Shop to ensure that our project is successful.

4. **Treating teammates with respect and ensuring they uphold the ethical code [1]**

We are in daily contact with one another to ensure that we are both aware of our responsibilities to maintain the necessary progress on our project and meet deadlines. Through this constant contact, we have offered and received feedback from one another, and in the process, have come to understand the value each individual contributes to making the project successful. The communication we have established has allowed us to be fully conscious of each individual's work to ensure that it is consistent with the ethical code.

References

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