SMART BACKPACK / BOOKSHELF

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1. Introduction

1.1 Objective

A problem that students have been facing for a long time has been overstuffed backpacks that are too heavy. Carrying heavy backpacks can not only cause temporary issues, but also chronic back and neck problems later on in a student's life [1]. A study conducted by Inland Empire Spine Center in Riverside, CA showed that 64% of students carrying backpacks reported having back pain at some time, out of which 90% described their pain as "bad" or "very bad" [2]. Although the causes of these problems are clear, students continue to carry overstuffed backpacks to school and put themselves at the risk of developing chronic spine or back issues.

Currently, monitoring the weight of a student's backpack involves being in the presence of a scale in order to measure its weight. Oftentimes, a scale is not readily available which makes collecting measurements tough. Maintaining historical weight logs must also be done manually and can be a pain. To make matters worse, a parent or guardian is not always available to provide feedback and monitoring assistance in order to help a student break bad backpack habits. A smarter backpack system is badly needed to make it easier for students to develop and maintain healthy backpack habits.

1.2 Background

Any "smart" bookshelf designs on the market today have been designed to support a library system and aid in book positions and organization. An example for this is the 3M Smart

Bookshelf system using RFID [3]. The smart bookshelf solutions on the market today address different problems but not our specific problem.

The original solution approaches the problem by simply warning the user of their backpack being overweight instead of actually solving the issue at hand. The original solution proposes weighing the bag before use and getting feedback on the weight limits on an IOS application that is bluetooth enabled. It then serves as a fitness application and becomes heavily software based. We tackle the backpack issue by looking at the problem from a completely different angle. Very often, this problem can be solved by just packing the necessary books for a day of classes as this reduces the overall weight of the backpack. Our solution proposes packing “smartly” based on the schedule and avoiding the issue of an overweight backpack. It uses completely different sensors, Wifi instead of Bluetooth, and an Android application which is not the main focus of the project unlike the original solution.

Our design proposes a solution to have a lighter backpack based on a student’s schedule. Repacking a backpack on a daily basis is a task that most students avoid and prefer to suffer the effects of a heavy backpack. Our solution uses the schedule data provided by the user to indicate directly to the user which books to pack on a daily basis to avoid packing any unnecessary books.

1.3 High-level requirements

1) After the user inputs the schedule once, the entire series of operations performs in the correct order successfully using a single start signal, pressing the “pack” button on the application, which is provided by the user every time.
2) The device must light up all 16 LEDs either red or green within 100 seconds after the pack button has been pressed and will have an accuracy of at least 98%.
3) The application will play an alarm-like sound within 10 seconds if the user takes out the “wrong” book (a book which has a red LED under it).

2. Design

2.1 Block Diagram

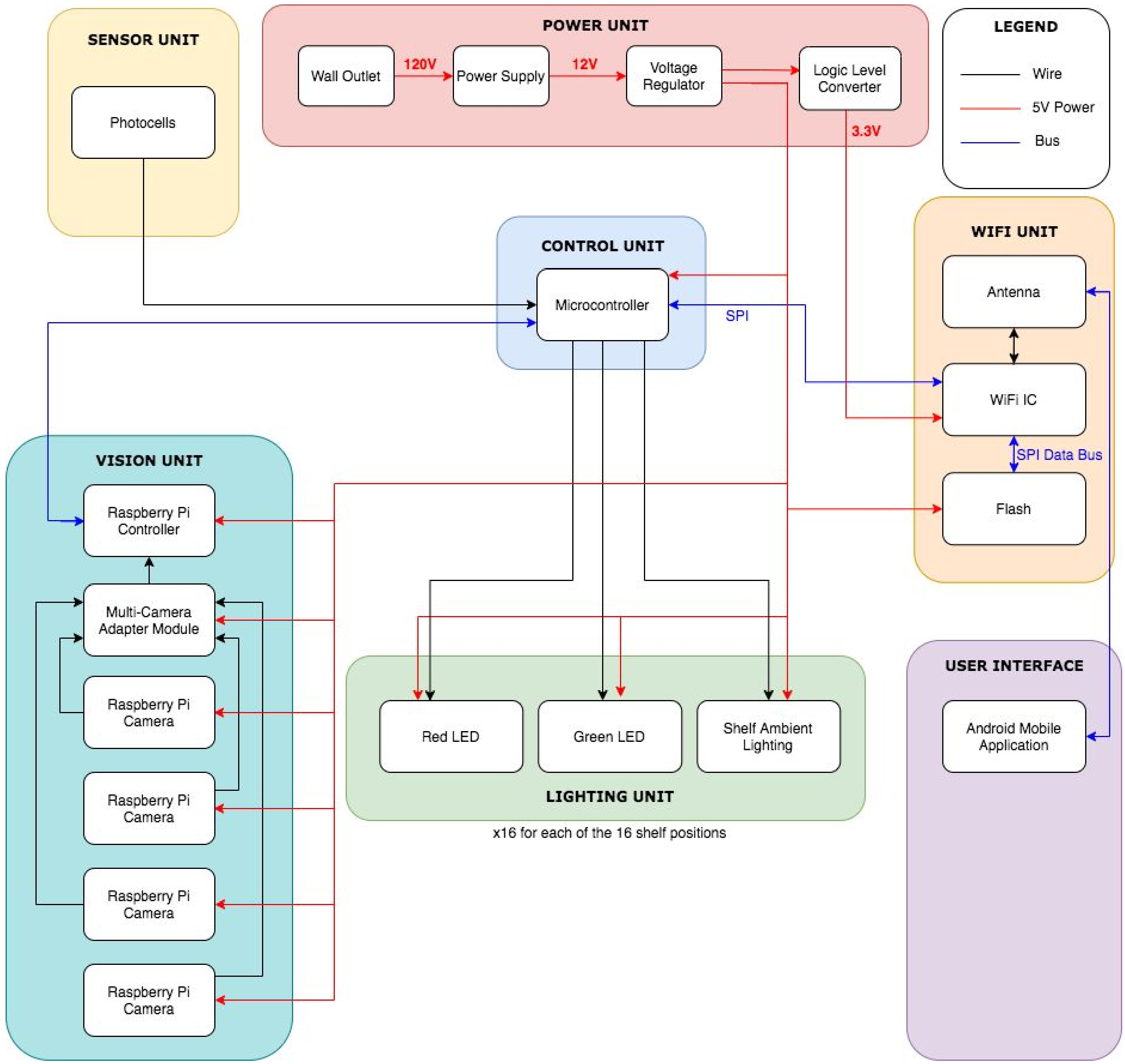

Figure 1: Block Diagram for our proposed design of the smart bookshelf

2.2 Physical Design

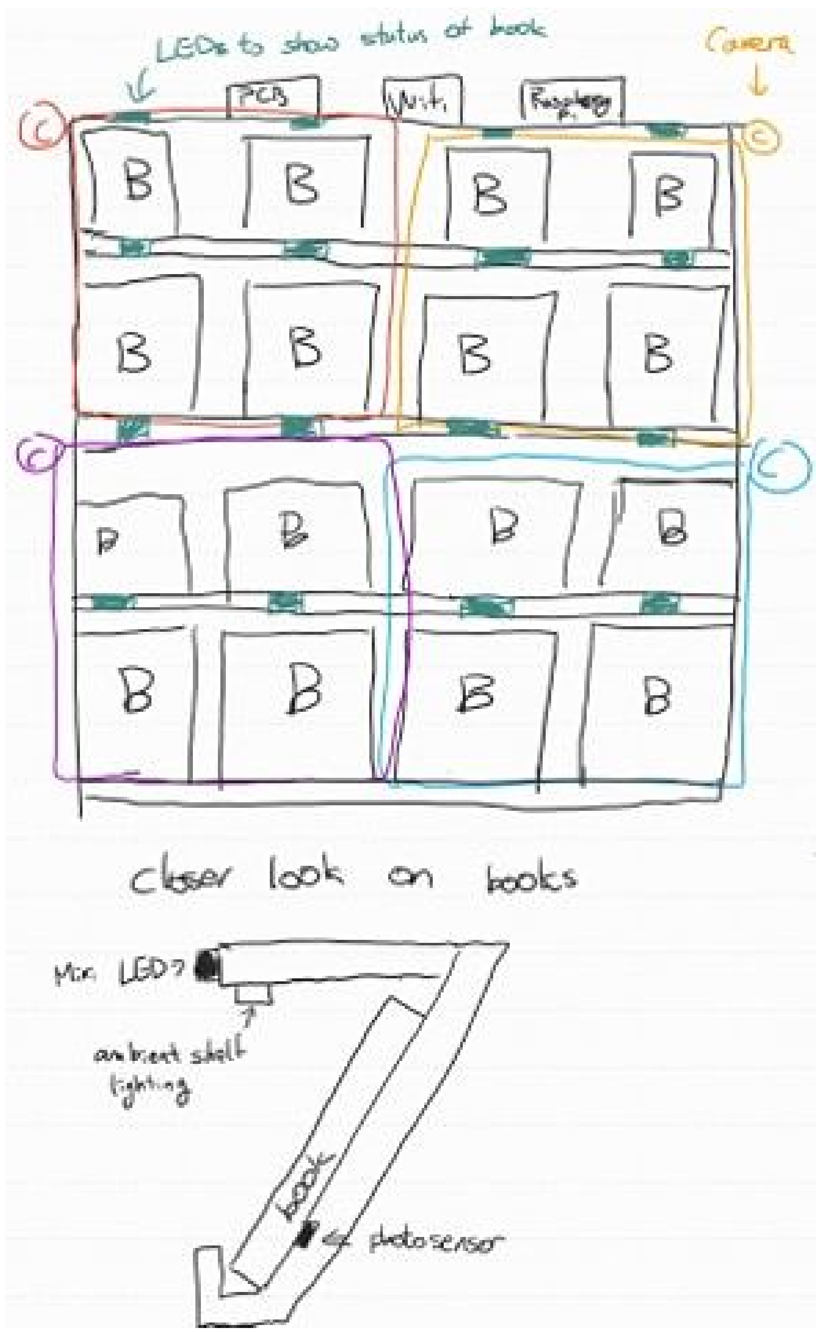

Figure 2: Physical design for our proposed design of the smart bookshelf

Figure 3: example of the book display shelf that we are going to use [4]

2.3 Functional Overview

2.3.1 Control Unit

The control unit will process the user input received from the user interface, and use the data to illuminate the necessary LEDs. It is responsible for carrying out the entire sequence of events by:

1. Receiving the day's schedule from the android application.
2. Receiving the image data from the cameras and data from the photocells and determining the respective positions of the books on the shelf. (This step is necessary for the system to know what book has been placed where)
3. Based on the schedule data and book positions, illuminating the LEDs for the necessary books with green, and illuminating the LEDs for the books not required red.
4. If an incorrect book is withdrawn from the shelf as indicated by the photocells, sending a notification to the android application.
5. If all of the correct books (labelled with green LEDs) have been withdrawn from the shelf, sending a notification of success to the mobile application.
6. Switching off all lights in the system when the process is complete.

2.3.1.1 Microprocessor

We will use the ATMEGA328P microprocessor. This microprocessor will be a part of our PCB and will be responsible for conducting all of the essential functions of the system. It will also be critical that all of the functions are executed in a sequential manner in the right order. Our microprocessor will also be responsible for communicating with the WiFi module using SPI.

2.3.2 Power Unit

This power unit will provide all of the necessary power requirements for the components of the system.

2.3.2.1 Power Supply

We are going to use a PLT 55-3075-99 step-down transformer. This will step down the standard 120V wall power to 12V that will be connected to the Linear Voltage Regulator for use in our design.

2.3.2.2 5V and 12V Linear Voltage Regulators

5V and 12V LM338T linear regulators will regulate 12V from the power supply, to 5V and 12V respectively which will be used by the microcontroller and input to logic-level converter for 3.3V which will be used by the sensor unit.

2.3.2.3 Logic Level Converter

This converter will be used to step down a 5V signal to a 3.3V signal for the WiFi module. The ESP8266 THING WiFi module we have chosen to use does not have inbuilt 5-3 logic shifting and requires a logic level converter, BSS138, to step down the voltage to the necessary 3.3V.

2.3.3 Sensor Unit

2.3.3.1 Photocell

The photocells are going to be placed inside the shelf facing the books so that we can know the state and position of the books on the shelf. This information of the state of books will go to the processor as analog data but will be converted to digital data in the microprocessor and will be coordinated with computer vision to help identify which books are needed for the day and change the status in the Raspberry Pi and the LEDs. Since there is ambient light, it is guaranteed that the removal of a book would trigger the photocell to inform the processor about the new state of the shelf position.

2.3.4 Vision Unit

2.3.4.1 Raspberry pi

Raspberry pi will be connected to the ATMEGA328P microprocessor, raspberry pi cameras. This will communicate with ATMEGA328P through SPI. Raspberry pi will be in charge of algorithm for the computer vision and matching the book placed on the shelf with the correct subject by reading the cover of the book.

For this, we are going to use a free version of OCR, Optical Character Recognition, API from OCR Space. This is workable for our project because for the free version, we can have 25,000 requests per month and 500 calls per day and this is more than enough for a highschool schedule.

2.3.4.2 Raspberry pi Cameras

4 Raspberry Pi cameras (5 MP, 1080p resolution) and a Multi Camera Adapter will be the eyes of Raspberry pi so that we can check which books belong to which subjects. Each of the cameras will be attached to the 4 upper corners of each quarter of the shelf. This way we will get the same viewpoint of the books (upper view) for more accurate comparison.

2.3.5 Lighting Unit

2.3.4.1 LEDs

We are going to use the Storm mini LED light circle to determine the status of the books on the shelf. Signals to these will be provided by our microprocessor to indicate which shelf has which books and need to be taken out. If the book on the corresponding shelf needs to be taken out, it will flash green. If the incorrect book is taken out from the shelf, it will flash red. This signal will be determined according to the schedule of the day derived from the application. The lights will turn on when the “pack” signal is received from the user and turn off when packing is complete as determined by the processing unit.

2.3.4.2 Ambient Shelf Lighting

We are going to use simple LED ambient lighting above the books when the “Pack” signal is issued by the user. This will allow the Raspberry Pi cameras to be able to identify the covers of the books. When the packing is determined to be done by the processing unit, the lights will turn off.

2.3.5 Wifi Unit

Data must be transferred between the user and the control module via SPI to be accessed on a WiFi network. Wifi Soc (System-on-a-Chip) operates based on an SPI flash program memory and uses an antenna to communicate with the user.

2.3.5.1 Antenna

Molex 1462200200 PCB trace antenna will be attached to the Wifi IC to gain maximum range. We will aim for 5Mbps access at 20m. This is within the specifications of the product and will allow the user to connect with the product within the boundaries of a household.

2.3.5.2 WiFi IC

ESP8266 THING Wifi Module is chosen for our project because it is very cost-effective and efficient for our communication. Our product does not require speedy transactions between the user so a cheaper model is used. It can operate at 160MHz when overclocked and has integrated power management units and Wifi transceiver. This module will communicate with the microprocessor via SPI.

2.3.5.3 Flash

ESP8266 THING Wifi module comes with a limited RAM memory of 12kb for user programs and variables/data. A Flash IC will be used, if necessary, to hold the program memory for the WiFi IC. This must operate at 80MHz for the WiFi microcontroller to operate at full speed. Currently, we are not certain of our program size for the microcontroller. We will prototype the size of 1Mb Flash IC and downsize for cost measures.

2.3.6 User Interface

2.3.6.1 Android Mobile Application

We will use an Android application to get the user's input the schedule of the week. The application will have a "Pack" button to begin the process. The application will also have a section to enter the schedule of the user to facilitate the packing process.

When the correct textbooks have not been taken out of the shelf, the system will send an alarm to the mobile application providing a warning to check your backpack, and return the unnecessary weight to the shelf. This application will be sending data to the wifi module which will in turn relay the information to the processing unit.

2.4 Block-level Requirements

Unit	Requirements
Control Unit	1. The microprocessor can process the computations within 1 second. 2. The microprocessor must be able to effectively communicate with all of the sensors used in the design.
Power Unit	1. Power supply provides 12V ± 0.2V when on and provides 0V when off 2. The voltage regulator must be able to output 5V +/- 0.2V for any input 3. The logic level converter must convert an input 5V signal into a 3.3 +/- 0.05V signal for use in the WiFi module.
Sensor Unit	1. The photoresistor must be able to measure within +/-5 lm of the actual light intensity in the bookshelf. 2. The photoresistor should not have a latency of 10 ms or more.
Vision Unit	1. The image data must be processed and the LED outputs must turn on in < 1 minute and 40 seconds. 2. The assignment of books to LED will have an accuracy of 98%.
Lighting Unit	1. All 16 LEDs must light up either red or green after the “pack” button has been pressed. 2. The LEDs must all go back to turning off (no light) 10 seconds after the user receives a notification that confirms that all the correct books have been taken.
Wifi Unit	1. Must be connected with 5Mbps access at 20m without obstruction / 5m with obstruction between the router and the module. 2. Must successfully be able to relay information such as the schedule with the corresponding subjects and the start signal from the application to the microprocessor.
User Interface	1. The application must have a “schedule” button for their user to input their schedule and take photos of their books. 2. A limit of 16 books must be set on the maximum amount of pictures allowed by the user.

	3. A limit of 2 subjects per book should be set as the maximum number of subjects for one book. 4. The application must have a “pack” button that runs the computer vision algorithm and lights up the LEDs after 30 seconds at most. 5. The application must send a notification 10 seconds after all the correct books have been taken out.

2.5 Risk Analysis

The greatest risk for this project will be the vision system. Our system depends greatly on whether the raspberry pi can read the words on the front cover of the books and determine which class the textbook is designated for. For example, the textbook cover could say “Introduction to computing systems from bits & gates to C & beyond” when it is used for both “Introduction to computing systems” class and “Computing systems and programming” class. The first case is easy because the name of the book and the name of the class is the same. To get over this, we would have to train or have a previous data set of list of classes and textbooks that the class uses.

Another criterion for success is the correct functionality of the application. The user will fill in a valid form of class schedule for the week and according to the standard AP and IB classes. Therefore there will be a limit to the number selection of classes that the user can input and this will be 38 AP classes and 56 IB classes. With a limit on the number of classes, it will be easier for the Raspberry Pi to determine which textbook belongs to a subject.

3. Ethics & Safety

3.1 Ethics

We would like to build a system that is accurate in finding the assignment of books to LED. Even though we would like the vision system to get the exact book assignments perfectly, it is one of our high-level requirements that we aim for an accuracy of ninety eight percent or above. We did this to be realistic and not lie about the efficiency of our product. We are abiding by the [5] IEEE Code of Ethics #3 by doing this. To alarm the users of which books to use, we use colored LED indicators: Green for correct behavior and red for incorrect user behavior. According to IEC 60601-1-8 standards [5], in the collateral standards, test and guidance for alarm systems in equipment is necessary using colors of indicator lights. Red indicates that immediate user intervention is required or used in dangerous situations and green indicates normal situations and equipment is ready to be used. We will be following the IEC 60601-1-8 collateral alarm standard and implementing the alarm system into the smart bookshelf.

3.2 Safety

We plan to address the safety concerns with a few precautions so that our users are not afraid to use our product. We would want the alarm system on the phone to not be louder than 70 decibels as that is the limit to safe listening according to the World Health Organization [6]. Another safety issue is that in domestic situations that this bookshelf could be damaged by the spilling of water or other liquids and that could cause a short circuit and ruin the components [7]. This is a risk and adding a rubber casing for some of the electrical components of the device such as the pcb, wifi, and the raspberry pi will make it safer to use for our scenario. These are the only important components that need to be covered because they are the only ones which are in the open.

Additionally, we will be using a converter to change 120 V to 5V for some of our devices which would avoid any potential electrical hazards. Since we will be working with wall power, we have to be extra careful with high voltage outlets. We will first test our project in a safe lab environment where we have a guaranteed 5V source, then we will test our voltage converter to see if it does indeed provide a 5V source while using the one hand rule. This way, we will prevent potential damage to the sensors and microprocessors as well as ourselves. All these precautions comply with the lab safety guidelines.

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