R.O.B.O.T:

Red Owl Book Organization Tool

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Initial Project Document and Group Identification
Divide and Conquer

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1 Project Description

1.1 Motivation

Even though many people enjoy reading physical books, public libraries and physical book retailers have been decreasing in popularity in recent years. A common point of frustration is that public libraries and bookstores do not take inventory in real time like electronic book retailers. Although many prospective readers enjoy being able to sample books, the tendency of readers to hold on to books for a long time before checking them out makes inventory management a challenge. Though many modern libraries and retailers keep websites that can inform customers whether the book they want has been checked out yet, they cannot keep track of the books that are neither on the shelf nor checked out. Many books that may register as “available” on these websites are either being read by another customer, are lost, or may even be stolen.

1.2 Objectives and Goals

Our project aims to revolutionize book inventory management by introducing a smart bookshelf equipped with Computer Vision (CV) technology. Using an LED tracking system, this innovation promises a more efficient way to track the availability and location of books within libraries and bookstores. Moreover, it offers an enhanced user experience by providing real-time access to book information through a dedicated Android application and database.

The first goal of the project will be the construction of a bookcase equipped with a wide-angle camera on each shelf. This camera will be connected to a computer containing a programmable book database. The computer will be programmed with CV, enabling the cameras to detect in real time when a book has been removed from or put back on to the bookshelf. This information will then be communicated to the app, informing prospective readers whether the book they want is currently shelved.

A main deliverable of this project will be to use CV to increase data efficiency, accuracy, and reliability. For this project, we chose CV as opposed to conventional barcode scanners. This is because a barcode implementation would require moving parts, as well as proximity to the scanner. CV can identify multiple objects simultaneously, can scan from a larger distance than barcodes can, and can update in real time.

In addition to an efficient scanning system, the project also aims to deliver a programmable app with an LED search feature. The physical bookshelf will be lined with a strip of LED lights that each correspond to the location of a book. The search function in the app will be paired to the LED lights. After searching for a book within the app, an LED corresponding to the location of the book will light up, enabling the easy identification of available books.

Within the app, an administrator will also be able to toggle between Night Mode and Day Mode. During Day Mode, it is assumed that customers will be freely permitted to remove books from the shelves. Activating Night Mode, on the other hand, will cause an alarm to blare when a book is removed from the shelves. This anti-theft measure will ensure that valuable books are not stolen during store closures.

2 Requirements, Specifications, and Constraints

Currently, the team is considering implementing the smart bookcase by using cameras, computer vision, database, and a computer such as a Raspberry Pi to process the camera images and quickly scan books on the shelf.

2.1 Implementation: Using Computer Vision

Hardware

1. **Cameras**: These cameras will be small, wide-angled cameras that capture the horizontal view of the bookcase. Pictures taken by the camera will be sent to a computer for processing and scanning of books. The cameras could either be wireless or wired.
2. **LEDs**: These lights will be placed along the front, lower edges of the bookshelf to help quickly locate books by lighting up to give users the approximate location of the book being searched for.
3. **Power supply**: The power supply needs to provide power to the computer, LEDs, and PCB that will be used.
4. **Computer**: The computer can be a laptop, tablet, or Raspberry Pi that will manage communication between the cameras, LEDs, PCB, and software. Additionally, the computer will be responsible for receiving and processing images from the camera and updating the database. This computer should be able to power the cameras.
5. **Printed circuit board**: The circuit board will help to control information between the LEDs and computer by receiving commands from computer on which LED to switch on and off. The circuit board should have a serial communication module, power distribution and switches for several LEDs, and a JTAG interface for programming and debugging the PCB.
6. **Display touch screen**: If we were to use a computer such a Raspberry Pi, we would possibly need to implement a small display screen. This display screen could provide further interaction for users by allowing them to search the bookshelf and trigger an LED light book find.

Software

1. **Computer vision**: A program to help process and scan the pictures received from camera and update database.
2. **Book database**: The book database would receive and update information from the computer based on the information received from the images. The database would update the book statuses based on three different states: on shelf, checked out, or missing. The database could also keep track of dates and times books were last seen on the shelf.
3. **Application**: Optionally, there could be integration of an Android application for phones that users can use for searching and checking out books.

Physical Structure

1. **Bookcase**: The bookcase will hold the books and be modified to put the cameras in a suitable location. It will also be modified to potentially hold a display screen at the end of it. Wiring will be attached to it and hidden in the back.
2. **Camera pockets**: Basic 3D printed structures could be made to hold the camera and place it on bookshelf in a manner that is non-invasive and has minimal visibility for library users.
3. **Location markers**: There should be special markers on the bookcase to help the camera and computer locate and approximate the location of the book so that the best and closest LED lights up. These markers could be a variety of things including number stickers applied to the back of the bookcase above the books.

2.2 Constraints for Implementation: Using Computer Vision

Possible limitations and problems that could arise from implementing the smart bookshelf with computer vision could be:

1. Books without the title and author on the side of spine could require special case detection by the system.
2. If a book is stolen and/or missing, the system cannot track down the location of the book.
3. If a book is missing but not stolen, it could be that someone is currently reading it in the library. However, the current system design would not be able to detect such a situation.

Because books are formatted in many ways, and though most have the title and author on the side of the spine, there are also some that do not fit these criteria. Some books could also be in poor condition, so much that the color on the outside is fading away. Such book conditions could complicate our computer vision and database implementation. We are currently looking at methods of scanning that could serve as a "one size fits all." This could be implementing stickers, perhaps like barcodes, that every book can have on its spine on a location where it is accessible to the camera and is easy to detect.

Our system will only keep track of inventory within the bookcase, so another limitation is that the system itself cannot help to track down precise location of books if they are not within the view of its designated shelf. This provides little backup for books that can be marked stolen by our system.

Lastly, another situation that our system will not know how to account for is the fact that people at the library or a bookstore like to take books off the shelf and read them while hanging around. This is not a true "stolen book" situation, but if they are holding onto it for more than 4 hours, for example, our system might alert the book as missing and/or stolen, even if it is not. The system will not have knowledge on how to differentiate between the two situations.

3 House of Quality

To be completed in updated DC.

4 Block Diagrams

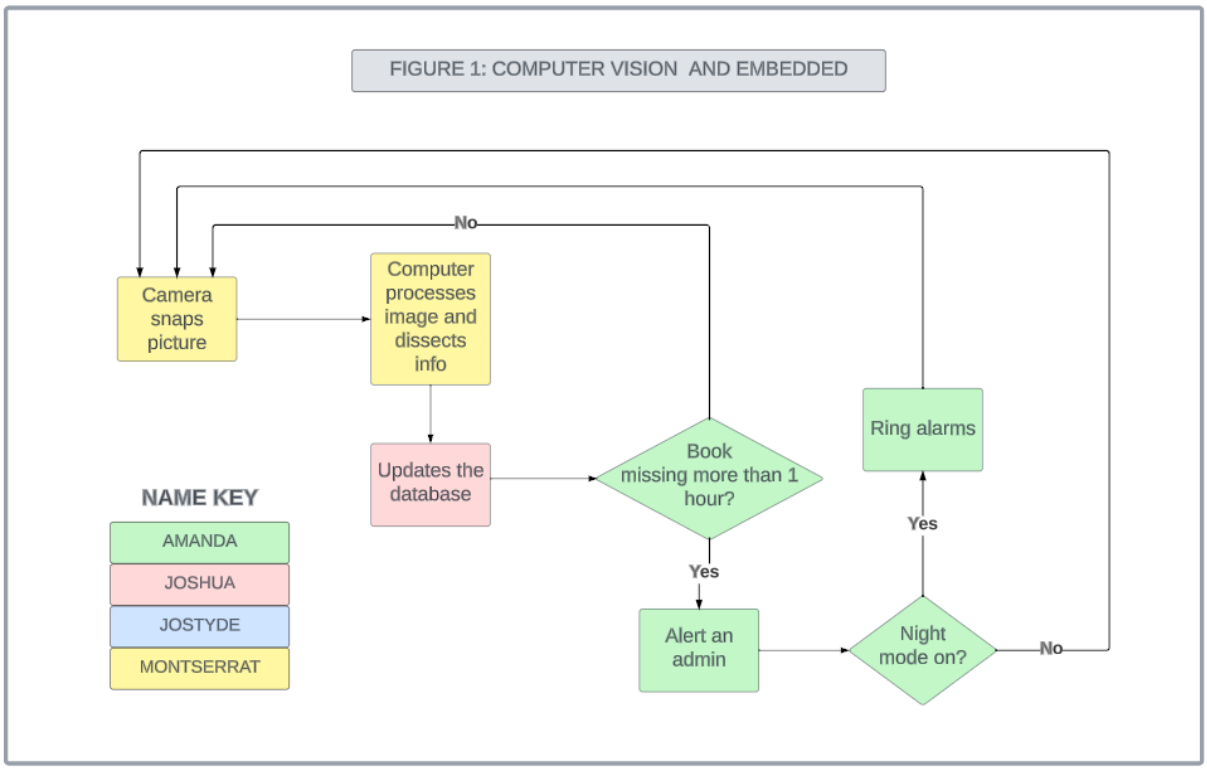
4.1 Tables: Work Distribution and Block Statuses

TABLE 1: WORK DISTRIBUTION BY AREA		
AREA	PRIMARY	SECONDARY
EMBEDDED	AMANDA	JOSTYDE
APP DEVELOPMENT	MONTSERRAT	JOSTYDE
PCB DESIGN	JOSTYDE	JOSHUA
COMPUTER VISION	MONTSERRAT	AMANDA
DATABASE INTEGRATION	JOSHUA	MONTSERRAT

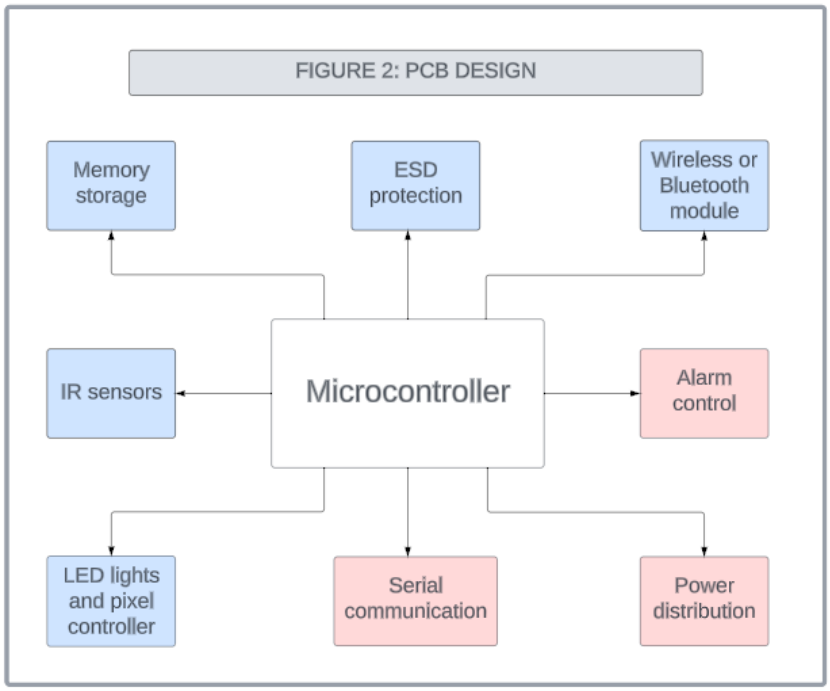
TABLE 2: BLOCK STATUSES	
AREA	STATUS
COMPUTER VISION	RESEARCH
APP	RESEARCH
PCB	RESEARCH & TO BE AQUIRED
CAMERAS	RESEARCH & TO BE AQUIRED
LEDs	RESEARCH & TO BE AQUIRED
COMPUTER	RESEARCH & TO BE AQUIRED
DATABASE	RESEARCH

4.2 Block Diagram 1: Software

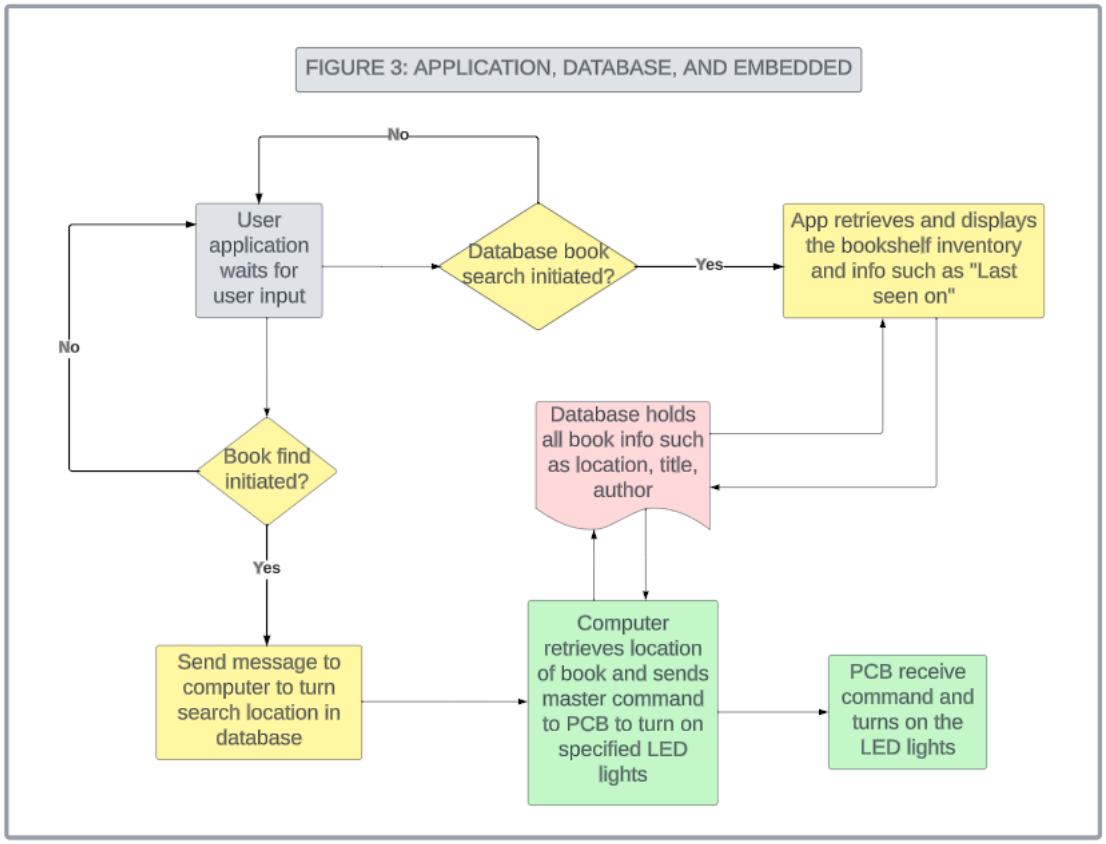
FIGURE 1: COMPUTER VISION AND EMBEDDED



4.3 Block Diagram 2: PCB Design



4.4 Block Diagram 3: General Operation & Procedure



5 Estimate Financing, Budget, and Timeline

5.1 Estimated Financing

Thus far, the project will be funded solely by the four members of the group. Considering our estimated budget and adding an additional amount in case of needing to repurchase several items, we are overestimating our budget to be $450 which will be split evenly among the four members; then, each member will contribute $112.50. During Senior Design 1, the group plans to reach out to potential donors and sponsors to bring down the costs.

Member	Amount to Contribute
Amanda	$112.52
Joshua	$112.52
Jostyde	$112.52
Montserrat	$112.52
TOTAL: $450.00	

5.2 Estimated Budget

Items	Price
Camera (wide angle)	$13.99 x 3 = $41.97
LEDs	$9.99
Power Supply	$11.99
PCB	$14.99
Display Screen	$49.99
Computer	$139.99
Bookcase	$20.90
IR Sensor	$10.99
Total Price: $300.81	

5.3 Estimated Timeline & Milestones

Task	Start Date	End Date	Description	Status

SENIOR DESIGN I				
Brainstorming	8/21/23	9/6/23	Discuss project ideas with team and meet with faculty members to get their opinion. Get three topics that group agrees with and discuss advantages and disadvantages of each one.	Complete
Project selection	9/1/23	9/6/23	Review and analyze previous senior design projects and how they were able to successfully complete their projects. Choose one final idea out of the three and consult with professors again to get their opinions.	Complete
Divide and Conquer Draft	9/6/23	9/15/23	Complete Divide and Conquer draft that will help to outline the hardware and software needed for the project. Assign roles to each person. Form project committee.	Complete
1st Meeting	9/20/23	9/20/23	Complete meeting with Senior Design I instructor and present Divide and Conquer draft.	Pending
Divide and Conquer	9/15/23	10/6/23	Fix draft based on feedback from Senior Design I instructor and project committee.	Pending
60 Page Draft	10/6/23	11/3/23	Begin working on 60 page draft document and expand on Divide and Conquer paper. Research PCB components based on required specifications.	Pending
2nd Meeting	11/6/23	11/8/23	Discuss and present 60 page document to project committee and Senior Design I instructor.	Pending
60 Page Report	11/8/23	11/17/23	Fix final 60 page report based on feedback from project committee and Senior Design I instructor. Begin ordering parts for testing.	Pending
120 Page Report	11/17/23	12/5/23	Work together to finish 120 page report by December 5. Finalize design and order more parts for testing. Try to mock parts of project for testing and evaluation over the break.	Pending
SENIOR DESIGN II				
PCB Assembly	TBD	TBD	Finalize design for PCB and test on breadboards. Order a batch (5 or so) for testing. Test entire design with breadboard until PCBs arrive.	TBD
Testing and Redesign	TBD	TBD	Test design more and adjust as needed. Get input from project committee and Senior Design I instructor.	TBD
PCB Assembly 2.0	TBD	TBD	In case first batch of PCBs fail, ensure to analyze PCB schematic and routing for errors. Fix and reorder. Ask for help if needed.	TBD

Testing	TBD	TBD	Finalize physical implementation of project and test and test and test! Make sure project runs smoothly and is of good quality. Review website and documentation. Prepare for presentation. Ensure all group members are well versed in the jobs they were responsible for.	TBD
Final Presentation	TBD	TBD	Present project and prepare for evaluation.	TBD

6 Declaration of LLM Use

The team hereby declares that it **did not** use any sort of Large Language Model to support the writing of this paper.