Room Availability Tracker

ECE 445: Design Document

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1 Introduction

1.1 Objective

Problem:

Imagine needing lab or meeting space, but you check all of the open spaces in ECEB to find that everything is full. It's impossible to currently check for available lab spaces in many rooms in ECEB, such as the study rooms, 385 labs, or 445 labs without manually visiting all of them and checking each room to see if there is space for you and your team. This means that aside from coordinating a time to meet with your group members, you must also ensure that the lab space or workspace that you are looking for is not filled. This can be problematic and can cause an inefficient use of group meeting time.

Solution Overview:

We propose a camera system that would allow you to check a room through a website before you leave your bedroom. At a high level, our solution is to utilize computer vision to identify the amount of lab seats that are available. This process involves using a camera located somewhere in or around the room that can view the chairs. This system would be able to take in an image, and perform some analysis on the image that would allow us to determine the number of open seats. This data, along with the room information, would then be sent to our server. The image itself would not be sent over the internet and would be deleted by the microcontroller. This server would then publish the data to a website or app frontend.

1.2 Background

There are reservation systems in some parts of campus such as the library called SPACES [1]. This program allows students to reserve meeting spaces, but does not cover lab benches in educational buildings. There is also a ECE department specific reservation system, so that only ECE faculty or students can reserve space [2]. However, this only allows TA or approved students to reserve lab space. Moreover, this system does not apply to the open spaces that are available to anyone at any time. Other solutions that we have seen include monitoring desktop computer usage in a room, as seen in the 391 lab [3]. However, this solution does not work in a lab or study space, because students may be using the room to meet or using the tools at a lab bench and not logged into one of the university's computers.

1.3 Visual Aid

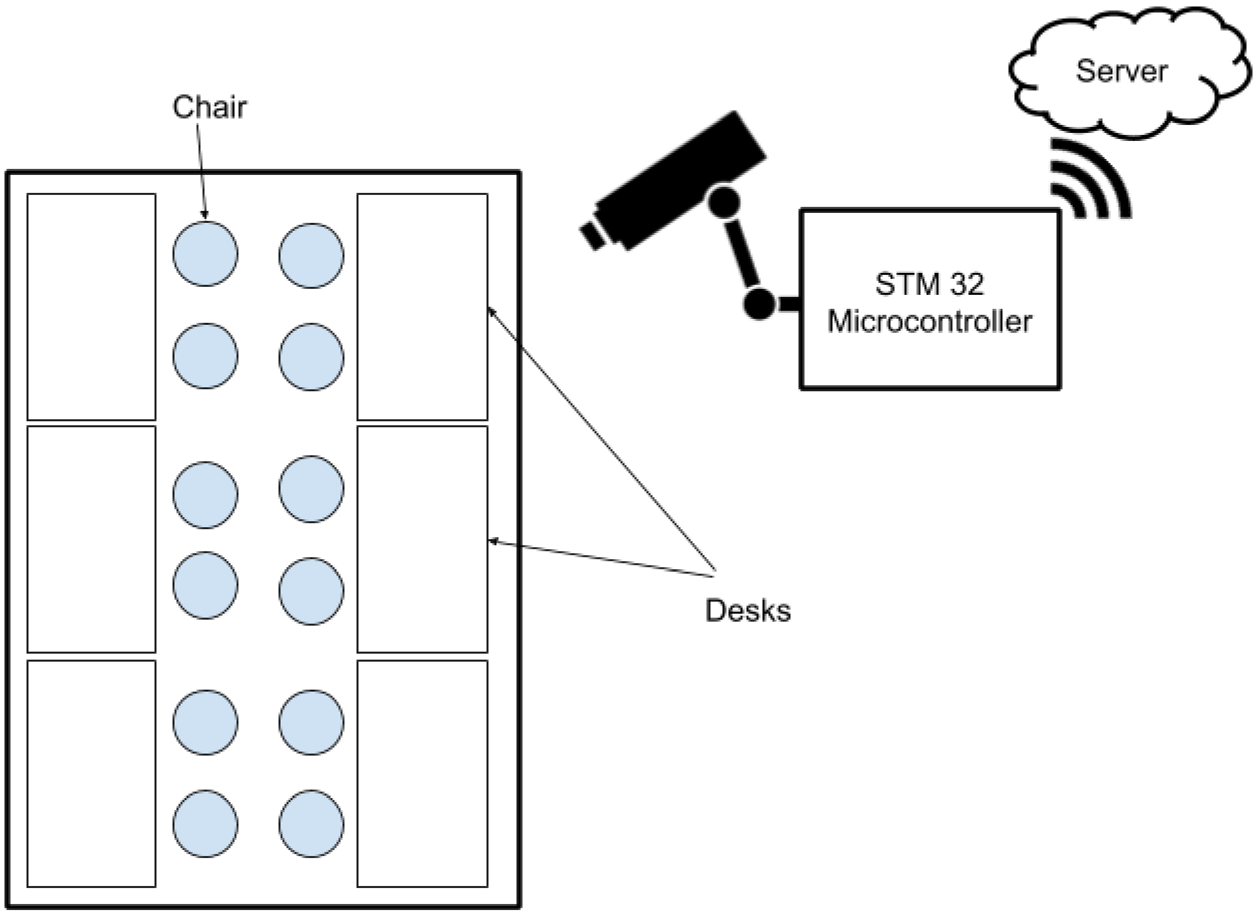

Figure 1: Lab Setup Visual Example

1.4 High-level Requirements

- The camera can take images every minute and pass that data to the microcontroller
- The microcontroller can process the image and send availability data of that room to the server
- The server can take in the data from the microcontroller and upload it to the website

2 Design

2.1 Block Diagram

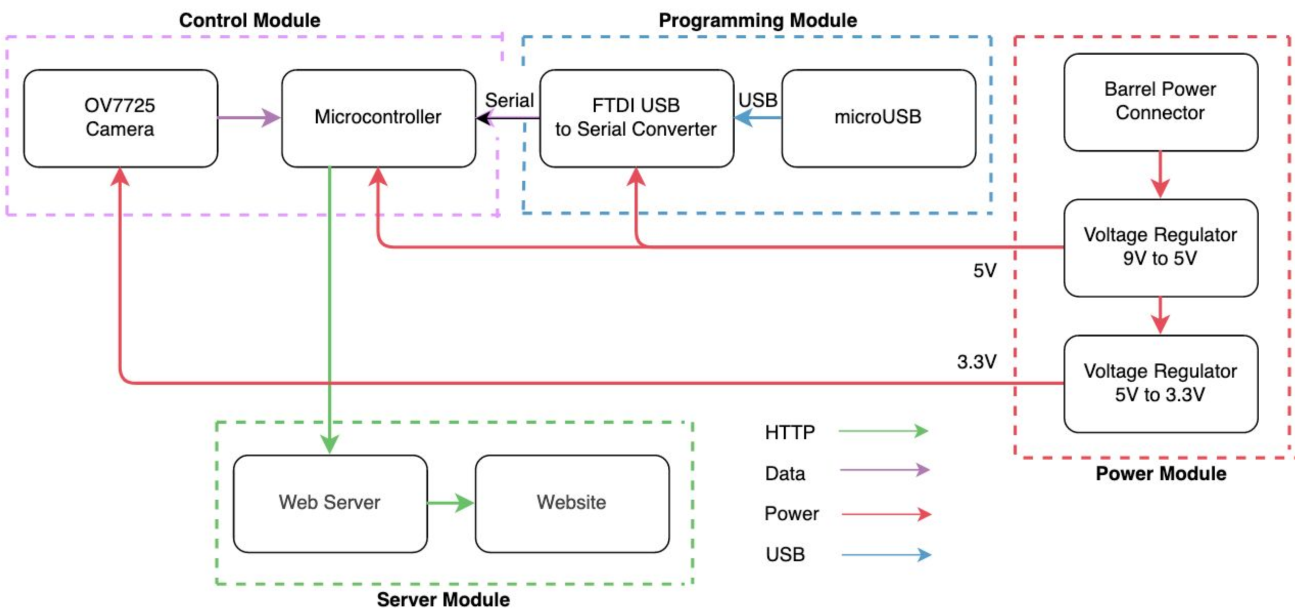

Figure 2: Block Diagram

2.2 Requirements & Verification Tables

Control Module

The control module is composed of the OV7725 camera and microcontroller. It will take pictures of the room and send the pictures to the microcontroller to be processed. The camera sends data via VGA at 60 frames/sec. The microcontroller would complete processing the image and send a number to the web server. This number would represent the number of empty spots available in the lab room.

The frame rate of the camera needs to be less than the refresh rate on the microcontroller. Frame rate is the speed at which images can be drawn, and refresh rate is how many times the monitor is refreshing the image [4]. If FPS is greater than the refresh rate, then the images aren't able to be drawn correctly. Our camera handles 60 frames/sec, which is equal to 60 Hz [5]. Our processor can handle up to

32MHz. This means we can process 32 images per millisecond, which works with our camera. The high processing speed is one of the reasons we chose this microcontroller [6].

The camera has an image area of 3985x2952 micrometers with a 6 micrometer pixel size. This leads to 665x492 pixels. However the camera can scale further past CIF (Common Intermediate Format). This is 352x240 pixels and is often used for real-time video. We can scale it down further to 244x244 pixels, and use this on the CNN, with 8-bit fixed point.

The microcontroller will run a convolutional neural net to determine the empty seats in the room. CNNs are known to run image recognition algorithms. To run the CNN, it needs to have 3 channels for RGB images, and 244x244 resolution.

Requirement	Verification
Camera can send image to the microcontroller	Take any picture of the lab. Connect camera to microcontroller. Send data to the controller.
Microcontroller can run CNN on image received	Take an empty image of the lab. Send this image to the microcontroller. Run CNN to determine the number of empty seats. Check if the result matches the actual number of seats.

Figure 3: R&V for Control Module

Programming Module

The microcontroller will have to process the image data and send the data to the server, so there must be a way to program the microcontroller. A microUSB to FTDI chip will convert the USB data to serial data. The serial data would then be sent to the microcontroller.

Requirement	Verification
Send data and code from laptop via Mini USB to STM32	Using Tera Term VT, we can connect the STM32 to the laptop via the microcontroller. If we press enter and get the message “OK” then we are connected and messages can be sent.

Figure 4: R&V for Programming Module

Power Module

We will use a barrel male connector to supply power. This 12V will go through two voltage regulators. The first is to regulate it down to 5V. This supply goes to the FTDI chip and microcontroller. The second regulates this 5V down to 3.3V to supply the camera. Using a barrel connector, we can connect the power to a 9V battery pack. The current and voltage requirements come from the draw from each chip. The camera needs a draw of 120mW during active mode and 20microW during standby. At 3.3V, this is about 37mA. The microcontroller only needs 100microAmps/MHz. This means that at 60MHz, we'd need 6mA. This leads to 30mA. The FTDI chip draws 15mA. The power draw on the regulators are negligible.

Total Possible Current Draw: 37 + 30 + 15 = 82mA = ~87mA (5% error from max current)
Battery Capacity: 500mAh
87mA for 5.7 hours

Requirement	Verification
Our battery must supply at least 87 mA for five minutes.	Connect a load and the battery, measuring current with an multimeter based on our calculations above.
The voltage regulator must provide 5V and at least 45mA to microcontroller and FTDI chip for five minutes	Connect input of regulator to the battery and output to a load. Discharge battery and check voltage at load with a multimeter.
The voltage regulator must provide 3.3V and at least 37mA to the camera for five minutes	Connect input of regulator to the battery and output to a load.

Figure 5: R&V for Power Module

Server Module

In order to let users access this data, we need a web server that could host the information on which rooms are full and which rooms are not. This server will implement a RESTful API that will have a specified list of devices that can post data to it (our microcontrollers). This information will be able to be read by anyone who has a valid netid login to the university.

Requirement	Verification

Server can receive data from the microcontroller	Connect microcontroller to server. Send any number to the server. Check on the database side.
Server displays data on website	Able to view data on the website

Figure 6: R&V for Server Module

2.3 Circuit Schematic

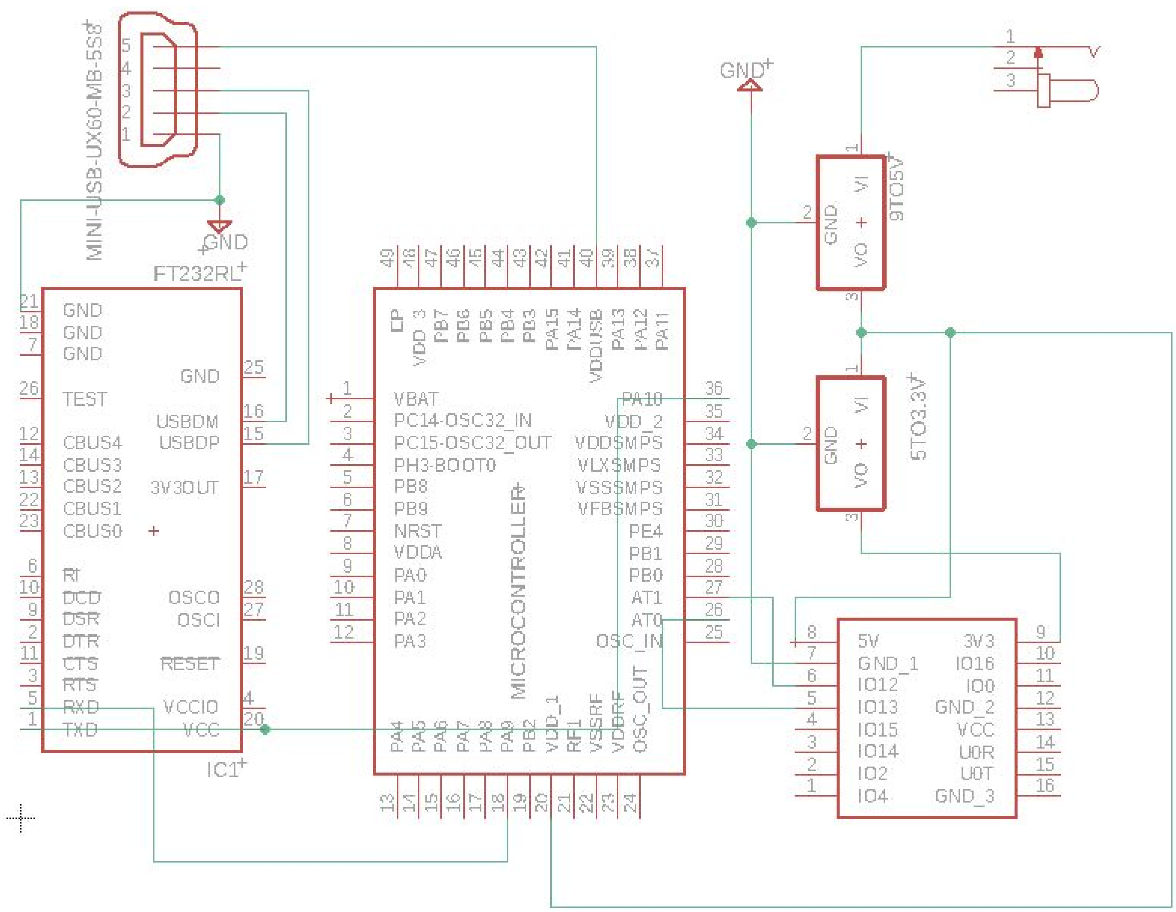

Figure 7: Circuit Schematic

2.4 Tolerance

According to the several results from these 8-bit neural networks shows that faces can be with over 90% accuracy [7]. This means that given our system will be using an 8-bit network and having images of size 244 x 244 as demonstrated by the STM manufacturers [8]. Since we are using systems that have already been validated, we can guarantee that our system will be able to correctly identify heads with an accuracy of 93%, thus allowing us to perform the necessary processing on the same devices. Since we are aggregating our results into less granular specifications, the overall accuracy will improve as a result of that. This allows us to have a guaranteed minimum accuracy of 90%.

The battery, a 9V battery, can supply 87mA for 5.7 hours, as it has a capacity of 500mA hours [9]. This means that we can run the device for 5 hours if we take pictures every minute.

The voltage regulator that converts our 9V to 5V supplies up to 1.5A and has a 2% output voltage tolerance. This means that the output voltage can range from 4.9 to 5.1V, which would still supply enough to the microcontroller and FTDI chips. The FTDI chip has a lower tolerance at 3.3 to 5.2V. The 5V to 3.3V can also supply up to 1.5A and has a 2% output voltage tolerance. This can supply from 3.234 to 3.366V, which is within the range of the camera.

2.5 Risk Analysis

The hardest part of our project will be the image processing on the microcontroller. One of the major ethical concerns is storing photos or video data of students in the open work spaces. To avoid this, we are planning to do all image classification on the microcontroller and then deleting the images (there will be no images sent over a network). We have chosen the STM32 because we have seen examples of this device being used to classify images, so we believe that this will work. The STM32 has a 32-bit CPU, 256 KB SRAM, and 1MB of flash memory that we can work with. This does not give us much space to hold previous data that can help in further prediction, so what may have been a simpler problem on a raspberry pi, will become much harder on a small microcontroller.

A second issue we could run into is the accuracy of the system and what we are displaying. We will need to have several iterations of weights in order to determine the most accurate method for showing the room availability. This could involve taking multiple pictures and using a voting system to determine the actual state of the room. We could also reduce the complexity of our output by showing a binary output on whether the room has seats available or not. This would be done in the case that we are not able to reliably produce the amount of seats available.

A third risk that could prove to be challenging to overcome is the actual algorithm run on the microcontroller. This classification problem will not be very easily solved, but there are a lot of resources to help us in this endeavor. Image classification has many feasible approaches, but certain things could cause issues like the lighting in the room being substantially different than expected, or some new object obstructing the camera. These types of issues will need to be acknowledged by our microcontroller such that we are able to determine if the results are inaccurate.

3 Differences

The project idea number 12 of Spring 2008 decided to approach this problem using load cells and heat sensors. Their solution put temperature sensors in either side of the cushions of each seat. Their goal was to design a wireless seat sensor that can determine if someone is currently sitting in that seat. They would use the weight sensor to determine if a weight was over 40 pounds, and a temperature sensor to determine if the chair's cushion reached a threshold temperature in order to then send a signal to their base module. This base module would aggregate the data from the room and then send that to a server which would publish the data to a website. This would allow people to see which seats are taken, and which seats are available [10].

In contrast, the project that we are proposing is one that will use cameras and microcontrollers to determine the amount of people in a room. Our solution is modular such that if more than one camera is needed, then the data can be aggregated on the server side. The devices will perform image processing and then send data back to the server consisting of the amount of people in the room, which room it is, and diagnostic information. This information will be aggregated on a server and published to a website, for people with university logins only.

A major reason that our project is an improvement is because of its versatility. Our solution can be set up in study rooms, and lab stations easily, and can add more modules for larger rooms. Our solution does not require every single seat to have an installed and working sensor. Their solution makes it harder for seats to be replaced, can be damaged if something spills or hits it too hard, and would be challenging to install on seats without cushions such as stools. Our solution can monitor more than one seat at a time, and can be adjusted and maintained easily.

The tradeoff with using our system is that our accuracy will not be as granular as their solution. Since they are placing their modules on every seat, they will have an accurate representation of the space 95% of the time. Our neural network with training can reasonably identify people's heads around 90% of the time [7]. In our solution, we plan on publishing less granular data such as mostly full or mostly empty, as opposed to there are 10 seats available. This should allow us to increase our overall accuracy in the correctness of our results.

Another metric to compare between the two solutions is the cost. From their cost analysis it appears that four modules cost around $318.37, with a majority of the cost coming from the load sensor cells - $23 a piece. When comparing that to our cost of $32.89 for more than four seats being covered, our solution is much cheaper. For their solution to add another seat costs at minimum $23 and for us to add another module would cost slightly more than that. Our camera can cover around 10 seats at minimum, and would be the cheaper solution in the long run.

Ultimately, the scalability, versatility, and modularity of our project makes it an overall better solution than the previously proposed project. There is a slight tradeoff when it comes to overall accuracy, but the benefits that our solution provides outweigh the disadvantages. Our solution can be placed in rooms without chairs and with stools while theirs cannot. The per unit cost of our solution is significantly cheaper, and the likelihood of damaging or tampering of our equipment is substantially lower.

4 Cost and Schedule

4.1 Cost Analysis

The total project costs are split between the labor needed to build the project and the parts that will go into the project. The labor analysis is as follows: 10hrs/(week/person) * 16weeks * $50/hour * 3 people = $24,000.

Item	**Part # / Manufacturer**	**Quantity**	**Total Price**
Microcontroller	STM32WB55VG	1	$10.51
Camera	OV7725	1	$8.95
FTDI chip	FT232R	1	$4.50
Voltage Regulator (9V-5V)	L7805CV	1	$0.50
Voltage Regulator (5V-3.3V)	LD1117V33	1	$1.95
DC Barrel Power Jack	SPC4077	1	$1.25

USB - Mini B USB 2.0 Receptacle Connector	UX60-MB-5ST	1	$0.99
9 Volt Alkaline Battery	NA	1	$4.24
Sum			$32.89

Figure 8: Cost of Parts Table

The total cost for this project, excluding PCB manufacturing, will be $24,000 + $32.89 = $24,032.89.

4.2 Schedule

Date	**Niharika**	**Katie**	**Nathan**
Week 1	Design Document draft Finalize design specs	Design Document draft Finalize design specs	Design Document draft Finalize design specs
Week 2	Design Review - finished Design Document Start PCB design	Design Review - finished Design Document Start PCB design	Design Review - finished Design Document Start PCB design
Week 3	Start microcontroller programming	Finish PCB design and order parts	Start classifying programming
Week 4	Work on Microcontroller code	Order PCB, verify, and test devices	Work on classifying programming
Week 5	Work on Integration	Work on microcontroller code	Work on server code and classifier
Week 6	Finish up Program	Solder PCB and work on verifying	Finish up Program
Week 7	Work on integration, testing, final demo, final presentation, and final report	Work on integration, testing, final demo, final presentation, and final report	Work on integration, testing, final demo, final presentation, and final report
Week 8	Work on integration, testing, final demo, final presentation, and final report	Work on integration, testing, final demo, final presentation, and final report	Work on integration, testing, final demo, final presentation, and final report

Week 9	Mock demo, final demo, final presentation, and final report	Mock demo, final demo, final presentation, and final report	Mock demo, final demo, final presentation, and final report
Week 10	Final demo, final presentation, and final report	Final demo, final presentation, and final report	Final demo, final presentation, and final report

Figure 9: Planned Schedule

5 Ethics and Safety

When reading the codes of conduct by IEEE and the ACM, we can see that the general trend is that engineers must take responsibilities for their actions, and that they must look out for the safety and wellbeing of the people. Our product does not get around any laws, and we will be careful about the technology that we are putting into the device.

When looking at the risks of camera systems that are on the internet, some of the biggest risks come from the continuous stream of image data that comes from the wireless camera [11]. This image stream can cause issues of hackers being able to identify your house given a stream of the data near you. Other instances of malicious use can be seen with the hacking of the Ring camera [12]. This problem also stems from the fact that there is prerecorded video on these devices or a live camera stream.

When processing images of other people, it is important to remember that privacy should be at the forefront of our minds. In order to be in accordance with section 1.6 of the ACM code of ethics regarding the privacy of others, we plan on only taking the images of others in public spaces, and are not sending that image data over the network [13]. This will allow the privacy of others to be preserved because the image data is being processed and then subsequently deleted before any information is sent over the internet. Since the system will only send the room number, estimated number of people, and some diagnostic information over the internet, we mitigate the risk of hackers gaining access to footage of these rooms because that footage will not exist for long periods of time.

When looking at the IEEE code of ethics part 1, we see that we must always be weary of the safety of the public when building and designing systems [14]. To comply with this, we do not want people outside of the university to be able to see the availability of the rooms, and by adding this layer of protection we believe that this can protect the university students from unwanted visitors in these public spaces.

Since our project will not be sold to consumers directly, the primary form of misuse could come from one of the larger clients. The way to attempt to ensure proper use is to not allow the technology to do the streaming of video because it would not be safe for that to happen.

Another aspect of safety is someone tampering with or hacking into our device. The largest method to mitigate this would be to install these devices securely and in places that are not easily accessible to the general public. In addition to having the system securely installed, we plan to mitigate this risk by having health checks sent to our server, so that our server can keep track of the data.

6 Works Cited

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