Room Availability Tracker

ECE 445: Final Report

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Abstract

There are a small number of open (non-reservable) study spaces in the Electrical and Computer Engineering Building. When students need a place to study or meet with a group outside of class time, they have to manually check each room or lab space. It would be much easier if there was a website students could check even before they left their apartments that would let them know if there was open space available in ECEB. A camera mounted in lab rooms could calculate whether space is available and output this to a website. This ensures that the data is not dependent on students being active participants, making for a more accurate, passive system.

Table of Contents

1 Second Project Motivation

1.1 Updated Problem Statement

Imagine sitting in your room in the middle of January, looking through your window at the blistering winds blowing snow around. You need to get to a lab, but know that it's likely to be busy right now. If there isn't free equipment, you would be venturing out uselessly. With a system to check all the open spaces in ECEB, you would know whether leaving the warmth of your room is worth it.

Unlike lecture hall seats, lab spaces and study rooms are coveted by students. The race to find seating in an open lab is more time-consuming than looking for a seat in a required lecture. Currently, it is impossible to check for available work spaces in most of ECEB, such as the study room, 385 lab, or 445 lab, without physically visiting the rooms and checking. This means that students will coordinate times to meet with their teams and then hope that a lab bench is available. When space is not available, group meeting time is squandered.

1.2 Updated Solution

Our solution is to use a camera attached to a microcontroller, mounted to the ceiling, much like a security camera. This camera could capture a small room, row of seats, or a subsection of a room. The microcontroller would then use the camera's images to perform object detection to find chairs and people in the room. The processed image will be used to determine how many seats are available. Based on the percentile of open seats, we report the availability of the room. This decision would be published to a website that only students and faculty would be able to access.

The original solution in Spring 2008 decided to approach this problem using load cells and heat sensors [1]. Their solution included placing temperature sensors on two sides 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 used the weight sensor to check if the weight on the seat was over forty pounds, and a temperature sensor to determine if the chair's cushion reached a threshold temperature in order to send a signal to their base module. This base module aggregated the data from the room. The room's data was sent to a server which published the data to a website. This would allow people to see which seats were occupied, and which seats were available.

Our solution is more modular such that if more than one camera is needed, for a larger room, then the data can be accumulated on the server side. For example, in the 445 lab we would need two devices, one for the left row and one for the right row. This data would be collected and displayed as one. The devices will perform image processing and then send data back to the server consisting of the availability of the room, which room it is, and diagnostic information. This information will be aggregated on a server and published to a website, for users with university logins only. We chose our solution because it is versatile and secure.

Other solutions that exist include the reservation system for rooms at the libraries [2]. This system allows students to make reservations for rooms, but not check their current state. This system is unique to the library, and while it does provide some help, it does not provide information on all the labs and study spaces in other educational buildings. Another solution can be found on the ECE 391 webpage [3]. The website tracks which computers have been logged into in the past half hour, and displays availability on the course home page. However, in spaces such as the ECE 445 lab, students may not be using the lab bench computer, which can lead to incorrect information.

Another proposed solution was to have a switch at each desk that marked it as “full” or “empty”. This would create a reliance on students to change the switch to on or off, responsibly. This requires a level of trust in the students not to walk away from stations for an extended period of time with their switch on, or to forget to turn the switch on in the first place. Because this assumes the students to not be malicious actors, we decided to pass on this proposal.

1.3 Updated High-Level Requirements

- The camera can take images every minute and passes 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

1.4 Updated Visual Aid

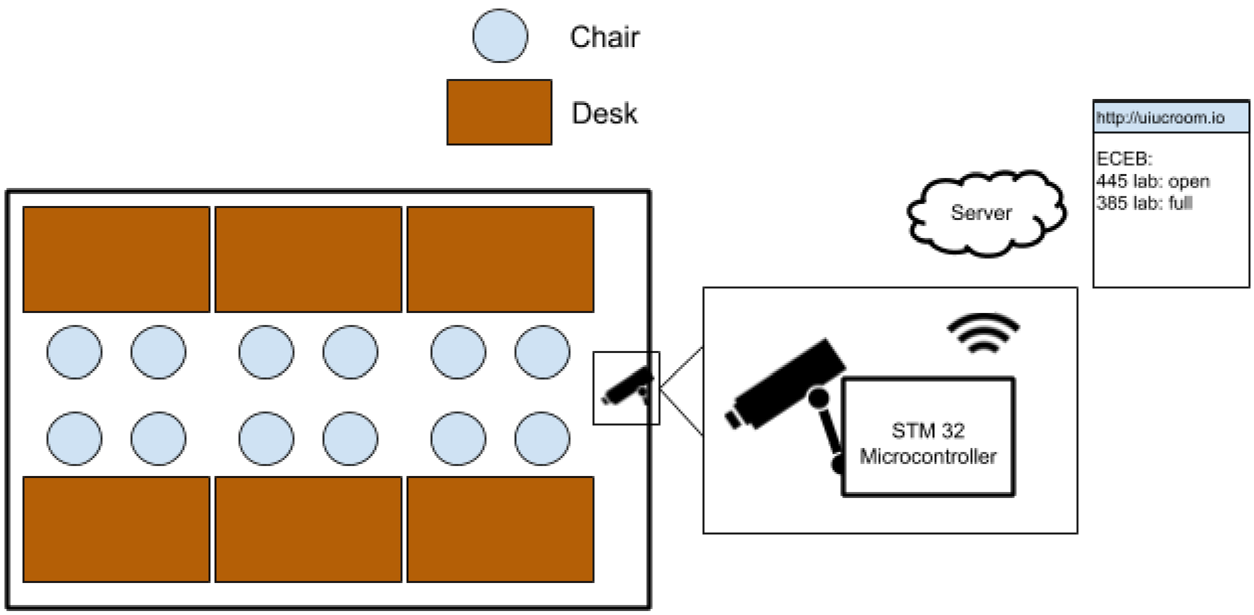

Figure 1: Lab Setup Visual Example

This is our visual aid for our project. The camera overlooks one section of the lab room and takes pictures. These pictures are analyzed by our microcontroller, and then sent to our server and website to display the information captured.

1.5 Updated Block Diagram

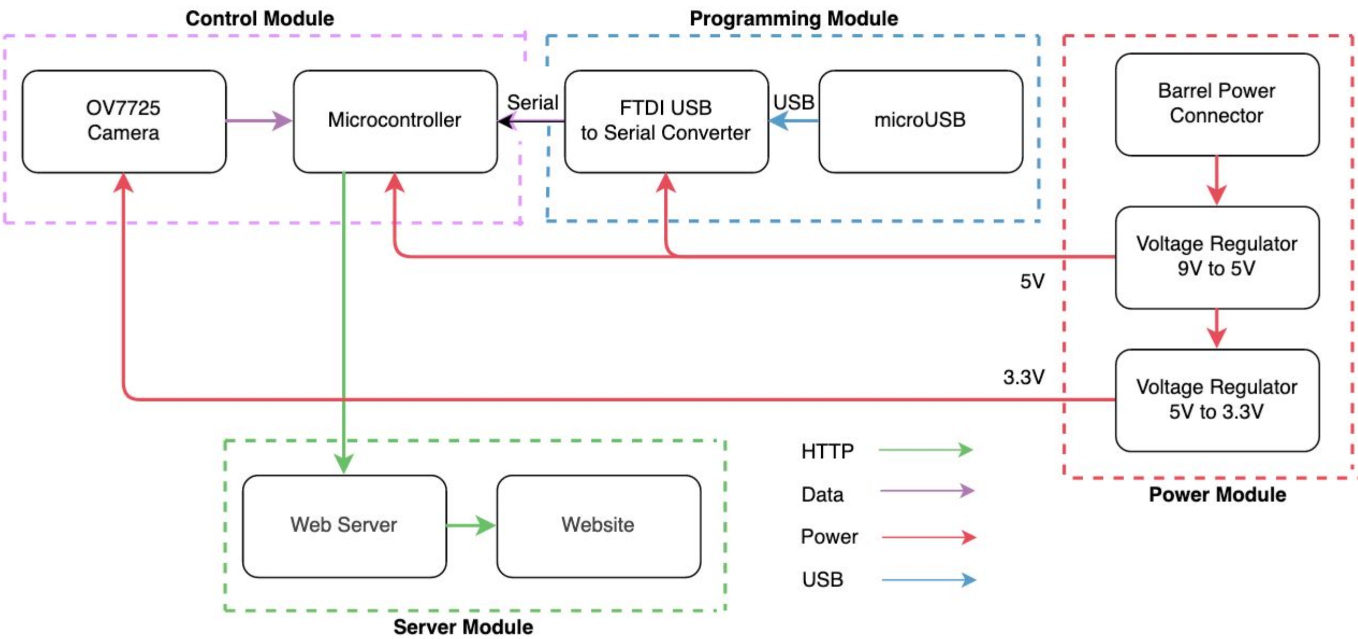

Figure 2: Block Diagram

We have four modules in our design. The control module is composed of the OV7725 camera and microcontroller. It is responsible for taking pictures and analyzing them to determine whether space is available in the room. The second module is the programming module, responsible for turning USB data to serial to be read by the microcontroller. The power module supplies either 5V or 3.3V. This travels first from the wall outlet, via the barrel power connector, to the regulators before arriving at the various chips on the PCB. The last module is the server module, which takes the data from the microcontroller and displays it on a website.

2 Second Project Implementation

2.1 Server Module

One of the critical components of our project is the server, which aggregates the data as well as the website that needs to display the aggregated data. We built a mockup of what the frontend would look like, given the data that the server receives. The image below is an example of what users would see when attempting to check the availability of rooms.

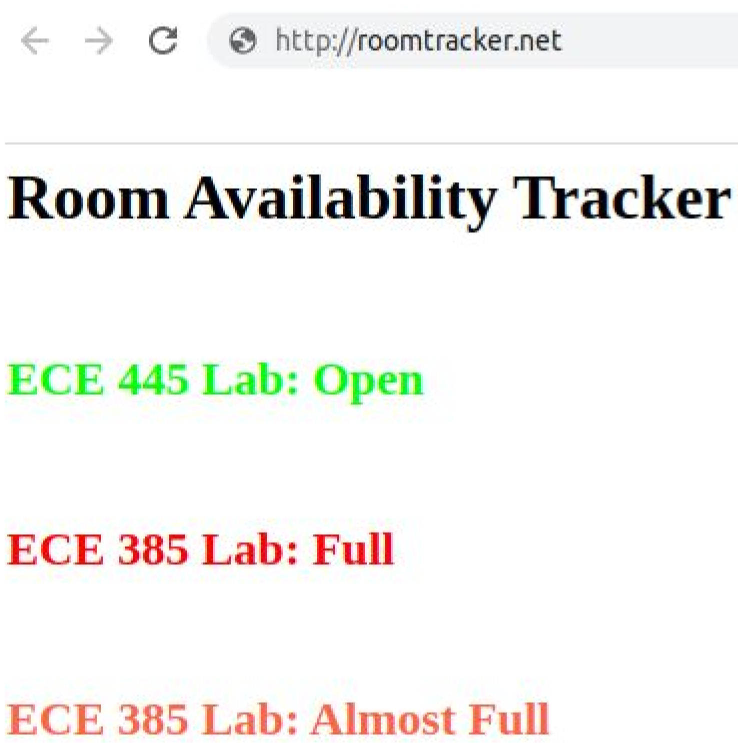

Figure 3: Rendering of the application webpage

The figure above shows the three types of availability: Open, Full, and Almost Full. If the room is labeled as “Open”, the system has determined that there is an ample amount of seating available in the specified lab or study room. This would be due to the camera subsystem determining that the room is at less than 70% capacity. The “Almost Full” label is used when the capacity is detected to be between 70% and 90%, inclusive. The final description that we are leveraging is “Full” which will be used when the camera system and server detects the room to be at greater than 90% capacity.

There are some cases where the server will need to be in contact with multiple camera modules for a single room. In these cases, the cameras will each be responsible for a subset of the room, and the server will be able to aggregate these results and determine the status of the room based on the full information.

One of the high level requirements is that the data can be aggregated on a server. This part of the implementations section is necessary because this is how we will display our results to our users. The server fits into the overall project by receiving and showing the data that we are collecting.

2.2 Circuit Design

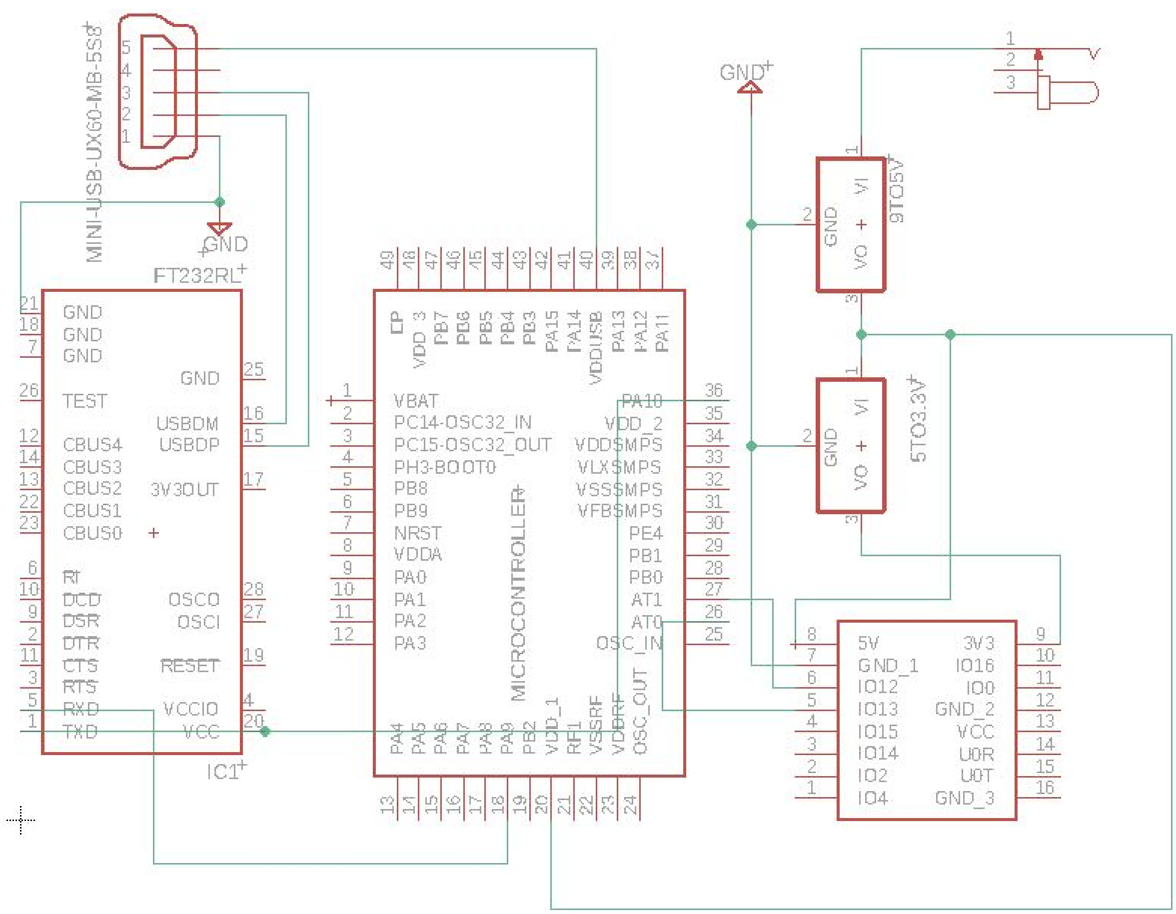

Figure 4: Circuit Schematic

This schematic describes how the smaller parts of our modules fit together. In the top right we have the mini-USB used for programming, and the top left is the barrel power jack to plug into the wall. On the right, from top to bottom, are our two voltage regulators, the first from 12V to 5V and the second from 5V to 3.3V. Using these we can accomodate the microcontroller which needs a logic level of 5V and the camera which uses the 3.3V. On the bottom right is our camera. In the middle is our microcontroller which connects all the subsystems together. On the left hand side we have the FTDI, which translates the USB data to serial data.

The circuit is necessary because it is the basis of our project. It connects all of the parts together, so that all of the requirements can be met. This is what will be on the PCB that, if we were creating this project, we could attach the PCB, which includes the camera to the wall.

2.3 PCB Design

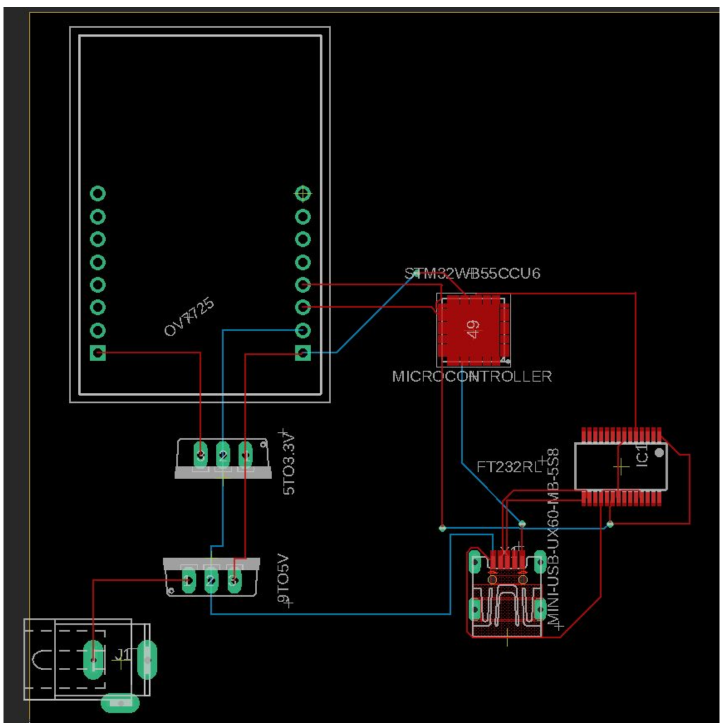

Figure 5: PCB Design

Figure 5 is our PCB design. We have our mini-USB and barrel-jack power ports on the bottom, so that we can plug in the port with ease. We also placed the camera on the top corner, so that it is easier to position this device and see the most of the room possible.

The PCB is necessary if we were to build a project because we would need to wire the components together, and using a breadboard is not sustainable for long term use. This piece of implementation supports the first two of the high level requirements because it allows the camera to transfer data to the microcontroller, and allows the microcontroller to talk to the wifi module built into this microcontroller.

2.4 Image Processing

The initial method we chose to use for image processing is a convolutional neural network (CNN). When researching current image processing techniques that can run on our system, we found that 8-bit networks with images of size 244 x 244 pixels can run well as demonstrated by the STM manufacturers [4]. According to their results, it appears that we could identify and count the number of available seats in a lab room.

In order to successfully test this, we need to train this camera system on each room. This is because the angle of the camera and the lighting in the room has a very strong impact on the network's ability to identify objects in images. For us to show that this methodology would work well, we have found other solutions where 8-bit CNNs have proven an accuracy on faces of over 90% [5]. This evidence proves that it would be possible to build such a system with the microcontroller and camera we have chosen.

Ultimately, we were not able to build this because we did not have access to the labs or the camera modules that we would be using. However, the research here shows how such a model could be built and trained to accomplish our object detection goals.

One of the high level requirements is that the microcontroller can process image data, and this section discusses the relevant parts of the image processing.. This section is necessary because this is how we will process our image before sending it over. The image processing fits into the overall project by being the core way in which we can identify the number of people in a room.

3 Second Project Conclusions

3.1 Implementation Summary

There were three main things that we have implemented and researched for this project. The first part wass the front end and server components that display the results of the system. Niharika worked primarily on the front end mockup and server side logic. The second major part of the system was the circuit schematic, and Katie primarily worked on that part. The last major part of the system that we implemented was the image processing research section. Nathan primarily worked on this by researching and discovering what has been implemented on the microprocessor that we were going to use and finding that valid networks have been built using this framework.

3.2 Unknowns, Uncertainties, and Testing Needed

Because of our circumstances, there is quite a bit of uncertainty in our project. We cannot order a PCB and put the actual circuit together to test our design due to the delay in manufacturing. A bulk of the uncertainty comes from not being physically present. We are unable to figure out the ideal positioning of the camera because we are not in the lab or a room where we could test our design. We also can't find the amount of error caused by different lighting conditions. Lighting will affect our design because the camera may give us better or worse images at certain times of day, and our accuracy may suffer as a result. Perhaps more importantly, we cannot collect any images of the room with differing amounts of people, so we cannot train our neural net on any useful data.

Once the coronavirus situation improves, we will be able to regain access to the rooms for which we planned on building these prototypes. This would allow us to take pictures at multiple points in the day at several angles to then determine which locations are best suited for placing the cameras. We would also use this image data to train our model so that we can improve our overall accuracy. This training is essential to building a working algorithm.

3.3 Ethics and Safety

While 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 their users. Our product does not circumvent any laws and the technology in the device was chosen carefully.

The control module, specifically the camera, holds some of the biggest risks. This includes the continuous stream of image data outputted by the wireless camera [6]. Hackers can use this image stream to track location data. Similarly, the Ring doorbell has been plagued with malicious incidents [7]. These problems stemmed from prerecorded video on the devices or live camera streams.

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 pictures of others in public spaces and are not sending that image data over any networks [8]. This ensures that everyone's privacy is preserved. All image data is processed at the edge and then subsequently deleted before any information is sent over the internet. Instead, our system will only send the room number and whether there is space available over the internet. This mitigates the risk of hackers gaining access to footage, as the footage will not exist for long periods of time.

In the IEEE code of ethics part 1, we can see that we must always be attentive of the safety of the public when building and designing systems [9]. To comply with this, we would ensure people outside of the university wouldn't have access to the availability of the rooms. University students would be protected from unwanted visitors in these public spaces with this added layer of protection.

Since our project will not be sold to consumers directly, the primary form of misuse could come from one of the larger clients. By developing the technology to not stream video, we can attempt to ensure that it is used properly.

Another aspect of safety is any sort of tampering with or hacking of the device. The best strategy to mitigate this is to install the devices securely and in places that are not easily accessible to the students or general public. This would include near ceiling tiles. In addition to having the system securely installed, our device could send random and consistent health checks to the server, so that the server can make sure all is working correctly.

3.4 Project Improvements

Refining Image Processing Approach

Given a year, we could refine the approach we're using to determine whether there is space in a lab room. Currently, we decided a CNN would accomplish our goal, but using a mixture model, could yield higher accuracies. Currently, we have a 10% error, as described in section 2. With better fine-tuning, we can bring this down.

We can also change our approach such that we wouldn't have to train in every room. Instead, we could develop a learning model that could recognize any chair in a picture. Once this is accomplished, it would determine all the chairs in a room and calculate the availability.

Number of Available Spaces

Currently, we determine - in a binary fashion - whether a room has available space or not. This was determined by the thresholds described in section 2. With more time, we could fine-tune our approach such that we can determine exactly how many seats are available. This could give users more information and help them better decide whether they want to leave their room or not.

Historical Data

Once we have the numerical data on the space in a room, we can keep a running tally of the availability. This would coalesce into historical data that will tell users when a room is most likely to be free. This can be used to plan meeting times and would be updated every day. This data could also be used by the school to have up-to-date information and consider trends about their investment in equipment and labs.

This kind of data could also be leveraged to perform some predictive analysis of room availability. Using the historical data we could build predictive models to determine the expected value of people on the room at any given time.

4. References

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