Project: Room Availability Tracker

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Introduction

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.

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.

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. It required large changes to the furniture in the room, whereas ours would add an external device, meaning that this is easier to implement in any room. With our project being modular, we could easily extend this to larger rooms at smaller costs because the cameras could cover larger areas. In the previous project the amount of equipment grows linearly with respect to the number of seats while our solution grows with respect to space.

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 non-image data to the server
- The server can take in the data from the microcontroller and upload it to the website

Design

Block Diagram

We have four modules to our project. The first is the power module, which will include our barrel power connector that will connect to a 9V battery, and then two regulators to step it down to 5V and 3.3V. Our programming module allows us to program the microcontroller. The server module will host and display data for the users. The control module runs the actual algorithm to determine the empty seats.

Functional Overview

Subsystem 1: Control Subsystem

The control subsystem will take pictures of the room and send the picture to be processed by the microcontroller.

Camera:

Requirements:

1. *Be able to operate in both high and low lighting conditions*
2. *Be able to take pictures in minute intervals*

Currently, we have looked into the OV7725 camera. This camera has both a high and low power option. The low power option can excel in low light conditions and operate in a variety of temperatures. This would make the camera suitable for object recognition. A single camera should be sufficient for lab settings or study rooms, which are significantly smaller than lecture halls.

Microcontroller:

We need a microcontroller that is able to handle image processing and wireless communication. This microcontroller will take in the image from the camera, check the number of available desks or chairs, and send this number to a server. We looked into the STM32 ARM microcontroller due to its high processing speed and wireless abilities.

Requirements:

1. *Be able to compress and process an image received from the camera*
2. *Be able to connect to a web server to send the number of available spaces*

Subsystem 2: Programming

We need a way to program the microcontroller while on the board. A microUSB to FTDI chip will convert the USB data to serial data. The serial data would then be sent to the microcontroller.

Requirements:

1. *Be able to convert USB to Serial so we can communicate from the laptop to the microcontroller*

Subsystem 3: Power

Battery:
We will use a 9V battery since the power system must be able to deliver power to all of our components.
Requirements:

1. *Be able to deliver 5V to the STM32 microcontroller [4]*
2. *Be able to deliver at least 120mW to the OV7725 camera at 3.3V [5]*

Active Camera needs: 11mA in active mode, 20 microA for standby mode

Voltage Divider:
We will need two voltage dividers: one for the microcontroller which will need 9 to 5V and one for the camera which will be 5 to 3.3V.
Requirements:

1. *Be able to deliver 5V from the 9V battery*
2. *Be able to deliver 3.3V from the 5V output from the first regulator*

Subsystem 4: Server

This subsystem would consist of 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.
Requirements:

1. *Be able aggregate data from microcontrollers*
2. *Be able to host data in displayable format*

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.

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 break any laws, and we will be careful about the technology that we are putting into the device.

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 [6]. 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.

When looking at the IEEE code of ethics part 1, we see that we must always be wary of the safety of the public when building and designing systems [7]. 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.

The other aspect of safety comes with tampering of the devices. 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.

Works Cited

[1] “Grainger Engineering Library Room Reservations”, 2019. [Online] Available: https://www.library.illinois.edu/enx/reservations/. (Accessed March 30, 2020)

[2] “ECE Illinois Room Reservations”, 2020. [Online] Available: https://reservations.ece.illinois.edu/ece/. (Accessed March 30, 2020)

[3] “ECE 391 Computer Systems Engineering”, 2020. [Online] Available: https://courses.engr.illinois.edu/ece391/sp2020/. (Accessed March 30, 2020)

[4] “STM32WB55xx”, 2020. [Online] Available: https://www.st.com/resource/en/datasheet/stm32wb55vg.pdf. (Accessed March 30, 2020)

[5] “OV7725 VGA product brief”, 2014. [Online] Available: https://www.ovt.com/download/sensorpdf/80/OmniVision_OV7725.pdf. (Accessed March 30, 2020)

[6] ACM, “Code of Ethics”, 2018. [Online] Available: https://www.acm.org/code-of-ethics (Accessed February 21, 2020)

[7] IEEE, “Code of Ethics”. [Online] Available: https://www.ieee.org/about/corporate/governance/p7-8.html (Accessed February 21, 2020)