Occupancy Monitor

Open Option Project - Fall 2017

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Our idea was to build a compact device using an Arduino board connected to an infrared (IR) camera module and mount it above any doorway. By taking only the IR image data from the camera, we then increment or decrement a counter whenever a person enters or leaves through the doorway, and display the running total number of occupants still in the room on an LED mounted to the device. Though the physical device was simple enough to implement, the software algorithm we developed and are in the process of refining was much trickier.

A potential method of image processing is shown in Figure 1. The first picture shows a crudely drawn IR image of 3 “people”. Real people will give off more complex shapes and intensities, but as long as they give off heat, they will all look like one continuous “blob” when compared to the colder floor. In the second image, we apply a black and white filter if our IR image is in color. This helps simplify the process of binarization. Many IR cameras will only provide our IR images in black and white, letting us skip this step. In the third image, we apply binarization to the picture. Binarization is a process of changing all pixels lower than a certain intensity to black, and all pixels higher than that intensity to white. This will allow us to separate the people from all other heat signatures and simplify the counting process.

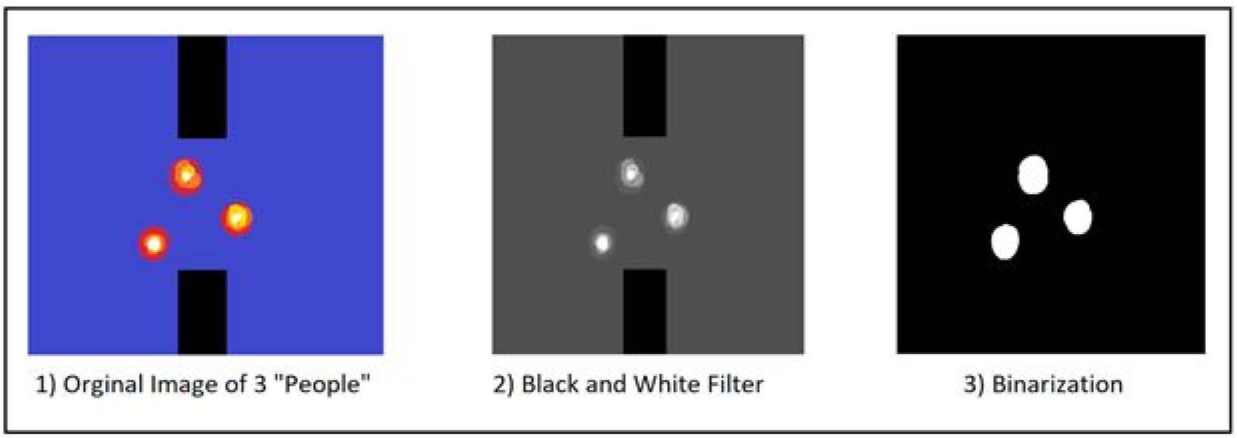

Figure 1: Potential method of counting people in images using binarization

We met with a marketing class in the College of Business to pitch our idea and got a lot of really great feedback. Without getting too deep into the technical aspects of our planned device, we explained how we came up with the idea, how we planned to implement it, and some of the ways we thought it might be useful in real-world applications. The marketing students then brainstormed in groups to give us even more ideas of how this device could benefit people. Some of the better ideas included counting the visitors in restaurants, bars, clubs, or shops and providing the business owners key information using that data; counting people in a stadium, concert venue, or even classroom in order to see exactly how many people showed up; and even using it in congested areas that are prone to people waiting in line for extended periods of time, in order to give more accurate estimates of how quickly (or slowly) the line is moving.

First Update:

We received the parts that we ordered and constructed a prototype, as shown in Figure 2. The prototype features a Teensy 3.2, which is a small microcontroller similar to Arduino, and runs using Arduino program files. This is helpful as we are already familiar with Arduino boards, but we do not want the large size of an Arduino board. This will be connected to an 8x8 pixel resolution thermal camera (model #AMG8833). We will be using this low resolution as a first "simple" step in solving the problem of counting one person as they pass through a door. When we are confident in our math and algorithms for solving this problem, we will then upgrade to a higher resolution camera and attempt to count multiple people entering or exiting through a doorway.

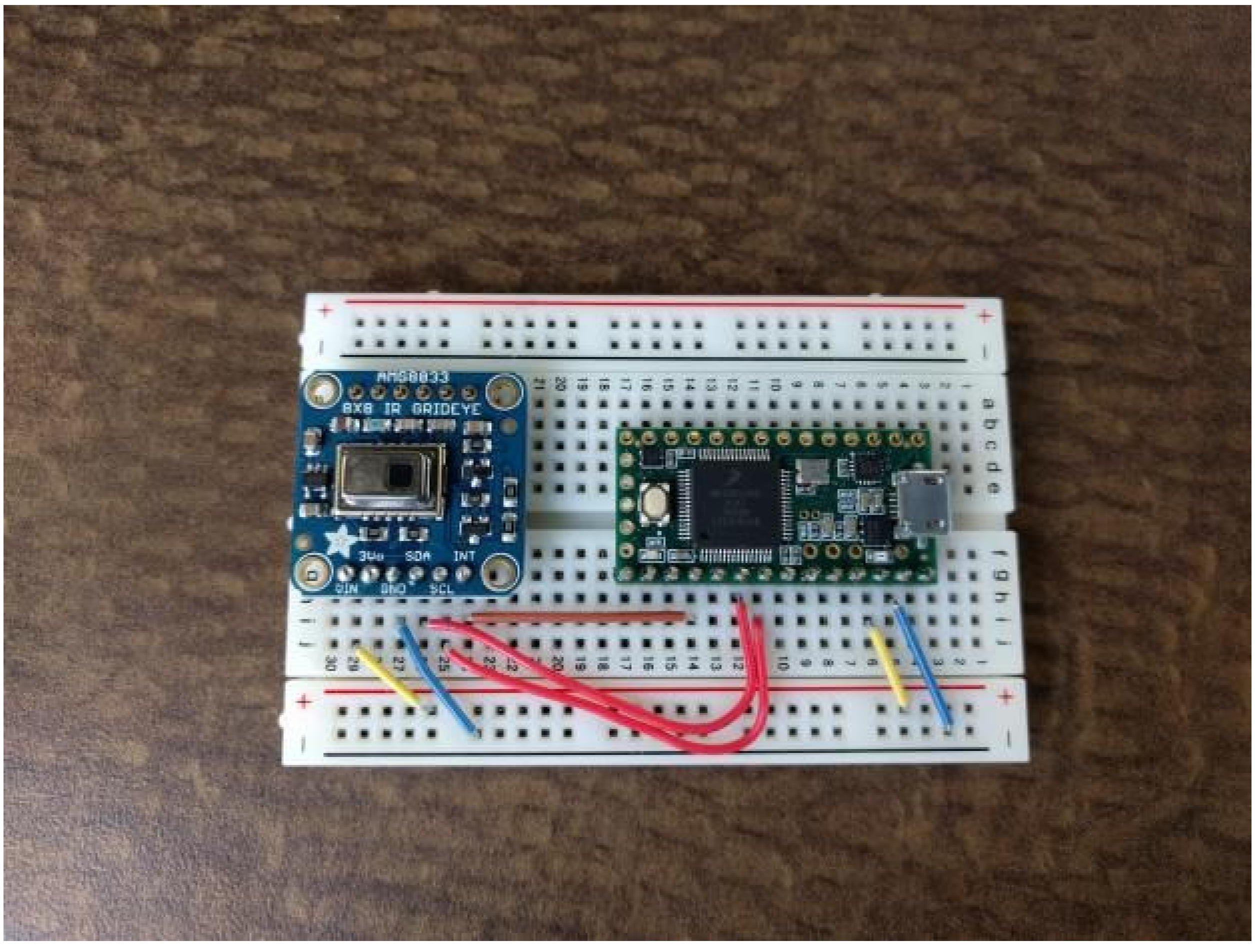

Figure 2: An AMG8833 thermal camera (left) connected to a Teensy

With the thermal camera being capable of processing images ten times per second (10 Hz), our prototype provides us with plenty of data. Starting off, the basic program we adapted from a free library displays an 8x8 matrix of temperatures, measured in degrees Celsius (Figure 3). In an ideal scenario, the background will be cold and people will be relatively hot. We try to differentiate the people from the background by using binarization as mentioned in our initial proposal. If a pixel in our grid detects a temperature below our threshold value (which will depend on the total average temperature viewed by the camera), it will drop to zero. This makes it easier to tell where people are, as well as how to detect which direction they are moving. We will then keep track of the person as their heat map ("blob") moves back and forth across the matrix. When the person moves across the center, we increment or decrement the counter, depending on their direction of travel. To find the center of the person, we can count every pixel that was higher than our threshold in both the x and y directions, and use that value to find the average on that line.

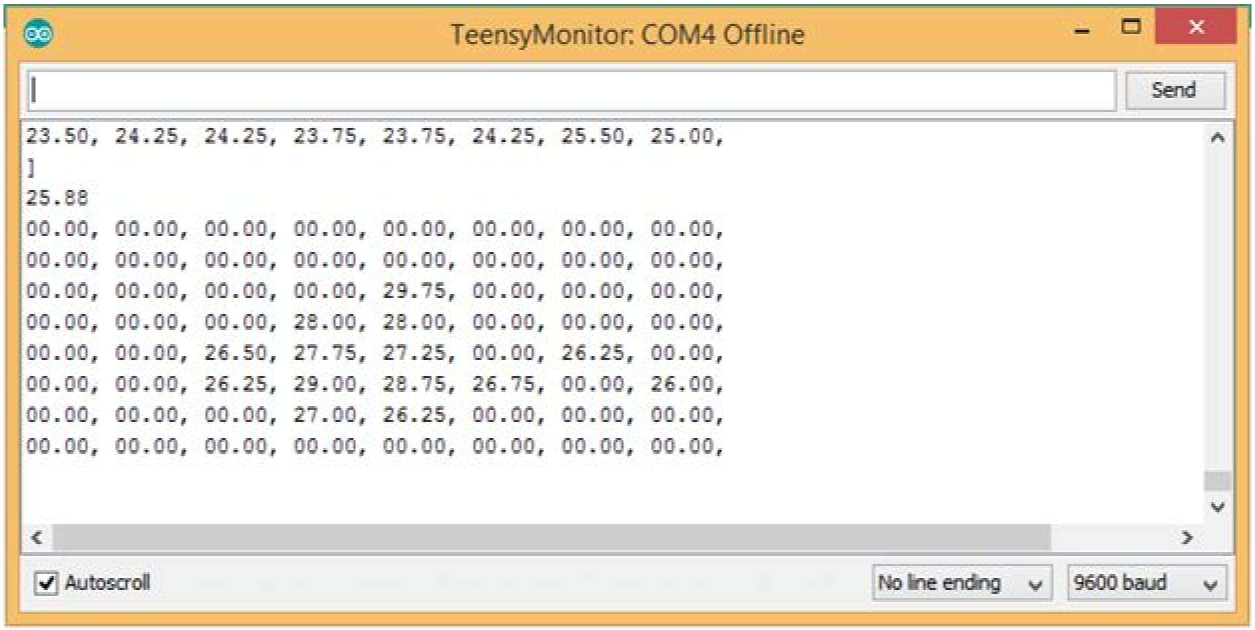

Figure 3: 8x8 grid of thermal temperatures. The 26-30-degree pixels in the middle represents Mitch sitting with a normal (room temperature) background behind him.

In order to track the movement of a person (and ultimately, multiple people), we plan to use shift matrices applied to each individual frame (matrix). We will take the first frame containing an object and perform shift operations in all directions to get a sense of which direction the person is moving. We can then add up these shifts to determine whether a person has moved enough that they have crossed the threshold of the door, thereby incrementing/decrementing the counter.

Second Update:

Our updated algorithm now allows the prototype to track one person at a time moving through a doorway, but only if they are the only heat source in image. For now, we are unable to track more than one heat source at a time because we are using a running average to find the center of only that single heat source (person). In the future, we plan to improve on our algorithm in order to incorporate the ability to track multiple people at a time. Some ideas we have of doing this is by splitting the image into separate images, each with just one object inside of it; or by using the running averages of spikes in the x and y directions, and breaking them into separate positions.

Final Update:

We previewed our project this week during the Open Option Project demonstrations, and we believe it went very well. We mounted the prototype above one of the doorways leading into the BC Infill area, and though we have not yet connected the LED display to the device, we were able to show visitors the heat map produced by our software on the screen of Lane's laptop, as well as the number of people the device had successfully tracked moving through doorway. Because the camera tracks movement relatively quickly, it was helpful for people to see themselves as groupings of pixels on the screen as they moved around the camera's field of view. Through many different interactions with engineers, teachers, and other students, we came away feeling good about our project and with even more ideas about how to improve on our idea in the future.

Concepts Applied from Other Courses:

To get the software side of things started once we had our prototype built, we used a fully functional library that came with the thermal camera and that was fully compatible with the Arduino. Using this library, we were able to learn several new concepts of C++ programming, and this led to us expanding the program in order to develop the algorithm we needed to track movement and update the counter. Furthermore, we incorporated several different techniques that we have learned throughout our schooling in order to help us efficiently build our prototype. We used our knowledge of algorithms and data structures (from various Computer Science courses) to help us develop the program and its efficient method of displaying each frame's values. We initially used concepts from linear algebra to help us determine the correct values of the matrix to be used for tracking heat objects, and while we did end up changing our approach to this challenge, our first method of doing this ended up being a solid launching point. We also used concepts from ECE classes and labs to help us construct the prototype on a breadboard, wiring the components together, and soldering the finished connections.

Future Plans:

We plan to continue with OOP next semester, and because of how much potential we believe our idea holds, we are excited to keep improving on it. Some immediate goals we have are: building two more prototypes, each with networking capability (Wi-Fi or Bluetooth), and synchronizing them in order to show that we can keep a running tally of the number of people in any room with more than one entryway; improving on our algorithm so that we can successfully track more than one person at a time; and finding a thermal camera with better resolution (but still not too expensive), so that we can apply some filtering techniques in order to more accurately scan the area directly beneath the top of the doorway.

Bibliography

Niklas, Felix. "Binarization." Image Processing - Binarization, 2017, felixniklas.com/imageprocessing/binarization.

Adafruit. "Adafruit/Adafruit_AMG88xx." GitHub, 29 Oct. 2017, github.com/adafruit/Adafruit_AMG88xx.