Distributed Climate Control: Human Detection To Reduce HVAC Energy Consumption

D. J. Coen, C. K. Sheridan, R. Simha, A. C. Cosma

The George Washington University
Department of Computer Science

Introduction

Heating, ventilation, and air conditioning make up 48% of the energy used in a typical U.S. home. HVAC makes up the largest energy expenditure of households, as well as many typical businesses. However, a great portion of HVAC resources are spent in locations where people don't even occupy, repeatedly heating and cooling the air surrounding nothing. This is waste of money, and energy which could be solved by our research: The Distributed Climate Control system.

This system will help businesses, homeowners, and other institutions save money on energy spending by dramatically reducing the amount of heating and cooling spent on air space that no one is occupying, as well as contributing to global efforts to create affordable, sustainable energy technologies. This project specifically aims to provide information specifying how many people are in a room, and where they are situated.

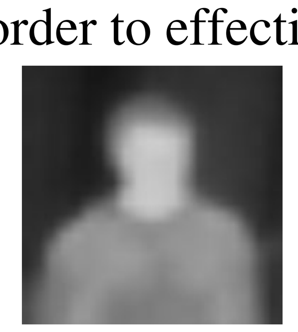
Methods

Feature Descriptor

Histogram of Oriented Gradients (HOG) is being used to create feature descriptors for positive and negative training samples. When detection is running live, a sliding window technique is used to scan an image for sub-images of multiple sizes, which are then resized for classification.

Human Classification

A Linear Support Vector Machine (SVM) was trained and used to make predictions on images real-time. SVM was chosen for both speed and easy comparison to other research projects. To test functionality, small sample sets of 100 positive and negative samples for both thermal and color images were created for training. These samples contained the head and shoulders of subjects in multiple positions, in order to effectively count people who are either standing or sitting.



Example of a positive thermal sample image

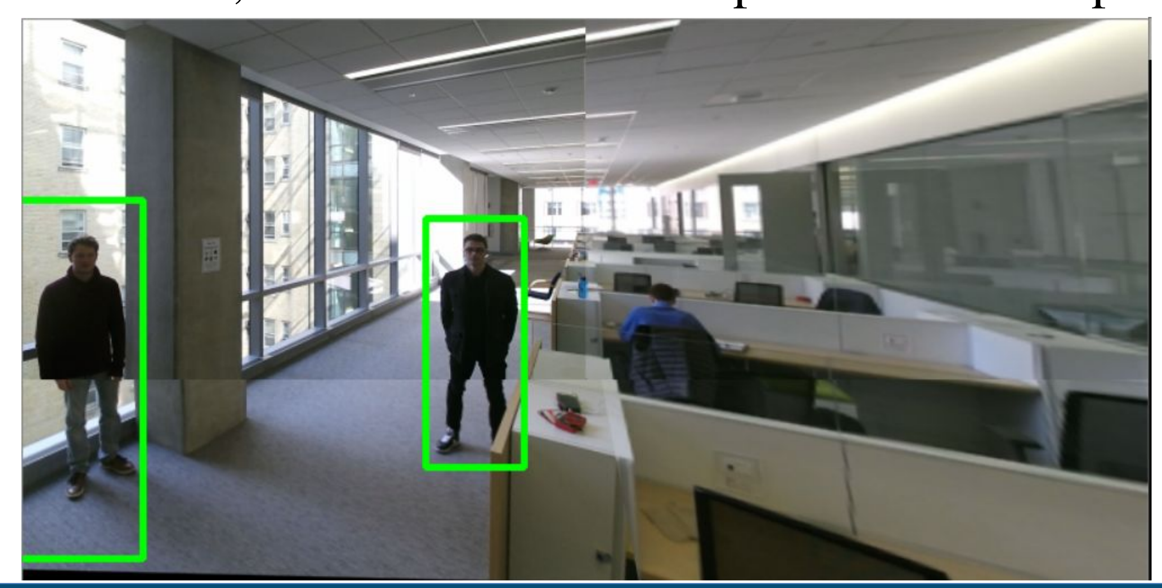
Panorama Stitching

The Field of View (FoV) of our cameras is too small to capture a room in one shot. To accommodate for this, we take images from multiple angles, then apply a panorama stitching algorithm to obtain a full view. Additionally, we take measures to ensure that the stitched color and thermal images line up correctly.

Matching keypoints for our stitching algorithm

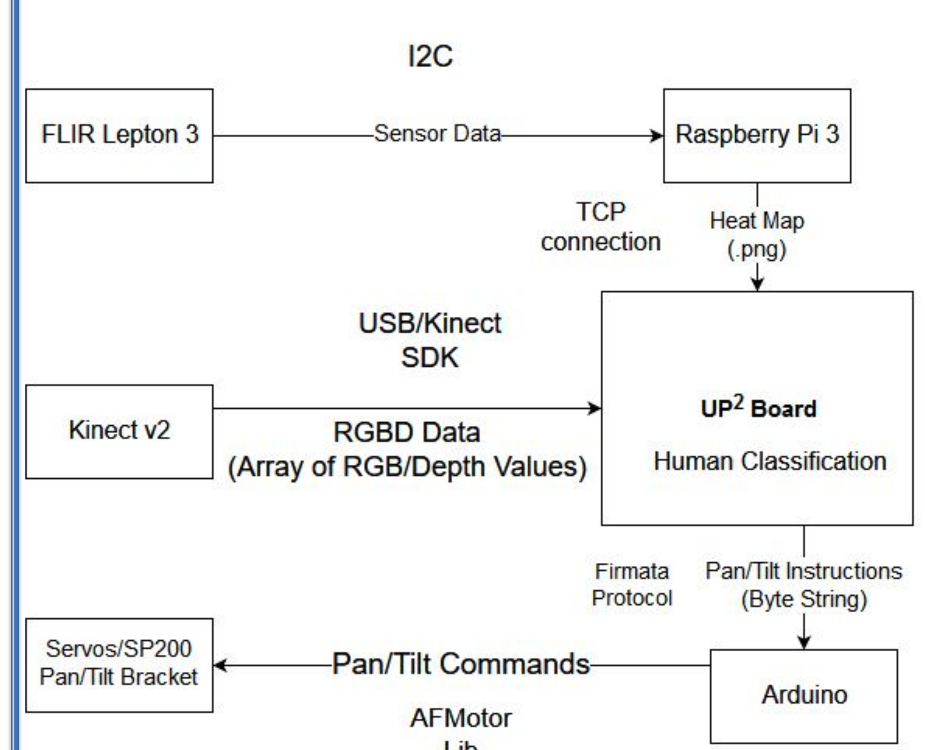
Objective

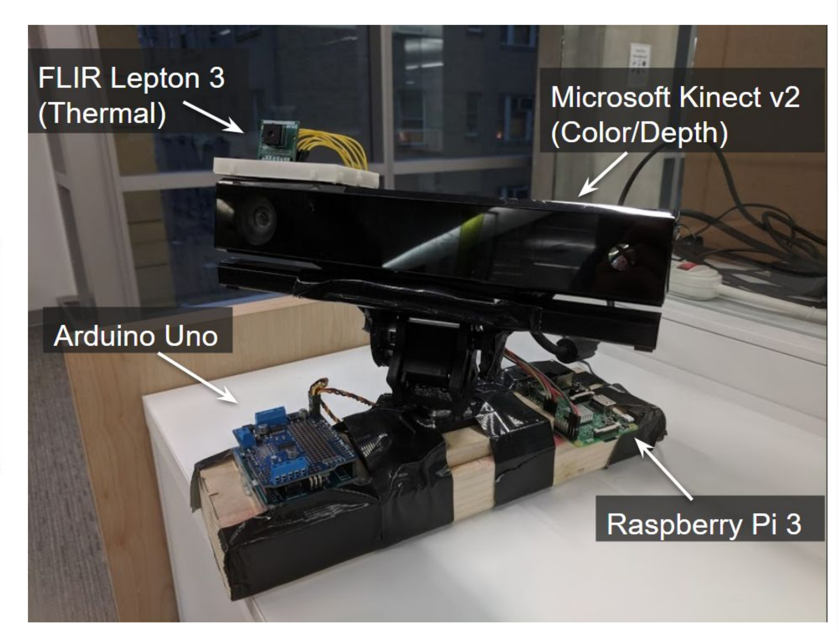
The objective of this research is to provide an affordable system that can continuously scan a room and accurately determine the number and locations of people in said room. Our solution involves using both a color and thermal camera, mounted on servos to pan and tilt to capture the room.



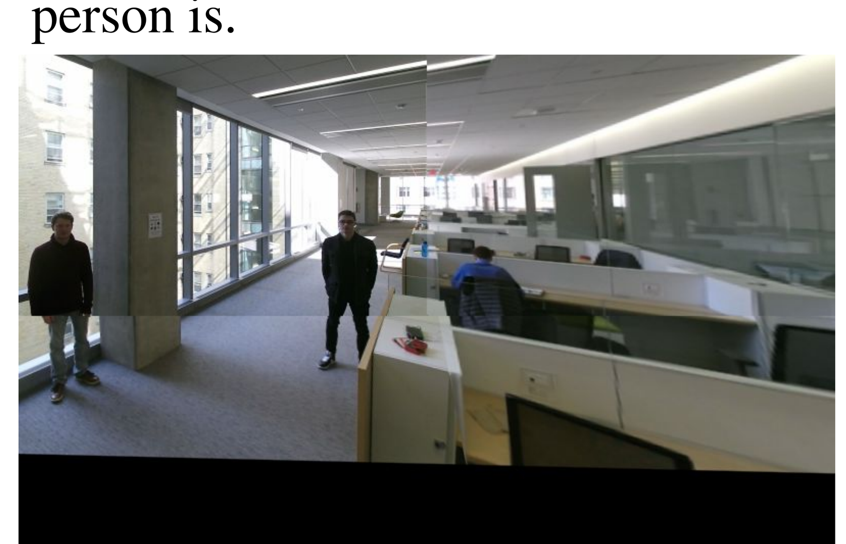
System Design

Our system involves the use of 3 SOCs (System On a Chip): A Raspberry Pi to collect thermal data, an arduino to control servo motors, and an UP board, or any windows machine, to act as a main control and processing center. The dataflow and an image of the current design is shown below:





Using DCC, we obtain color and thermal images from multiple angles, stitch them together, and then apply person detection on the resulting image. Above in the objective section, you can see the person detection being applied. Below, you can see the stitching being applied to both the color and thermal frames, such that we can accurately determine where a person is.

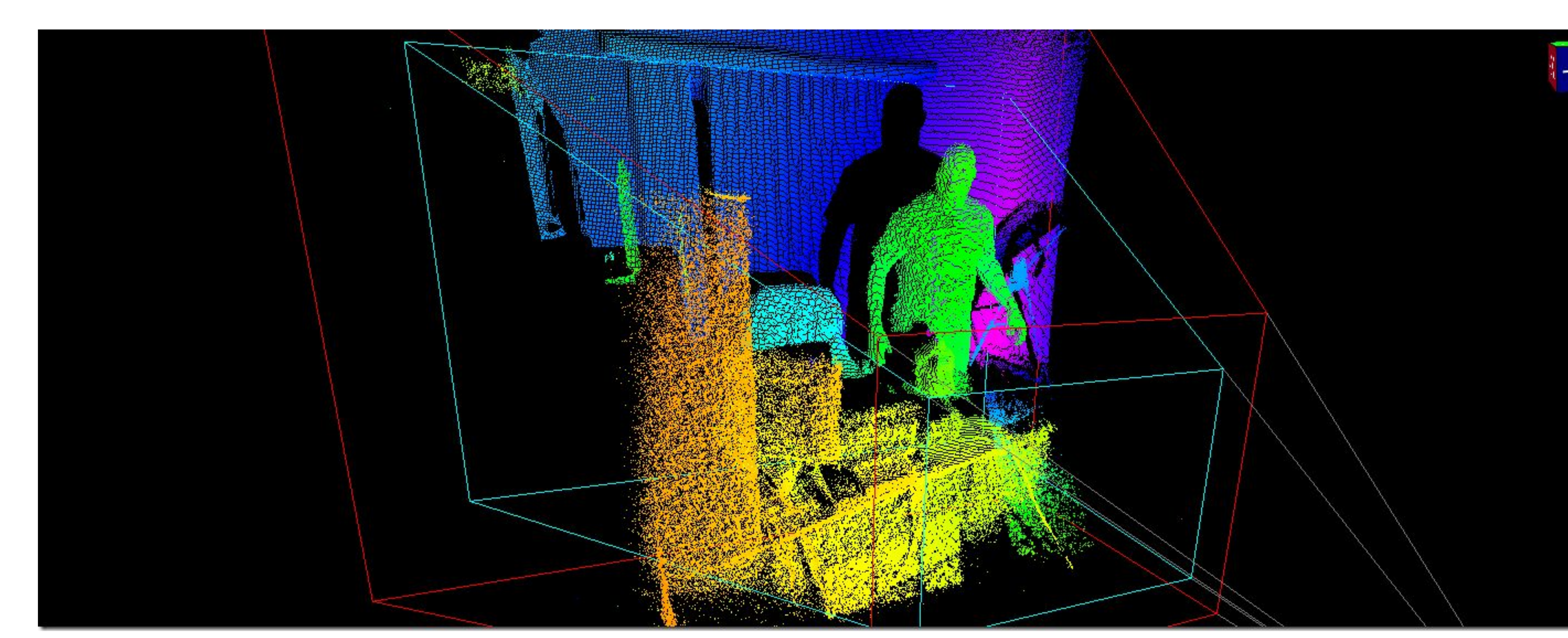


Discussion & Future Directions

The system currently is effective in its ability to detect standing subjects using the full-body pedestrian detection SVM trained on MIT and INRIA pedestrian datasets. On our training sets, we saw promising results for thermal images based on the head and shoulders descriptor of subjects. As it currently stands, there is not enough training data for both thermal and color images to train a model and have concrete results. The system easily can integrate more training data, as well as detecting different objects, such as the full body, or smaller features such as the head or limbs for future testing.

Future directions include combining the system with a predictive model to control temperature in spaces used at a regular time interval. for example, a conference room used daily before the work day would be preheated or cooled to a comfortable temperature for workers before they enter every day. Upon the meeting's conclusion, the HVAC system would automatically turn off in order to save energy.

Additionally, the system could provide information for monitoring personal climate zones using depth data. Rigid bodies could be tracked, or simple depth data could be referenced with respect to where people are detected in the color and thermal images. The temperature of occupants could then be controlled by several small HVAC systems distributed throughout the room.



Depth data captured by the Kinect V2 sensor

References

ARPA-E. (2014). DELTA - Delivering Efficient Local Thermal Amenities.

Dalal, N., & Triggs, B. (2005). Histograms of Oriented Gradients for Human Detection.

Rosebrock, A. (2016). OpenCV panorama stitching.