HEAT SENSOR - EMBEDAI

Max Pettersson
School of engineering
Jönköping University
pema16bu@student.ju.se

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ABSTRACT

The purpose of this project is to construct a method of tracking and counting people using a thermopile sensor from ROL Ergo AB. An 8x8 heat image was constructed with the data from the thermopile sensor, and Canny edge detection was used to detect and track human heat signatures in the image, after some image processing was done. Occupants were counted by looking at the size of the heat signature.

1 Introduction

Studies show that indoor environmental quality impacts the well-being of the occupants, and in turn their productivity [1]. Counting and tracking people in an office could enable companies to improve the workplace through automation of, for example, ventilation or control of lights. However, tracking people raises questions about how the privacy of employees are handled. For this reason, counting and tracking people using cameras may not be the most viable option. An alternate option is to track people using their heat signatures, which ensures the anonymity of the tracked person. One way of detecting heat signatures from a distance is using a thermopile sensor. This sensor represents heat in an matrix where each element contains a heat value. Even though this sensor has a far lower resolution than a regular camera, detecting objects and object-occupant interactions is possible from such such a sensor [2].

2 Task description and data construction

This project explores a method of tracking and counting people in a room using heat signatures from a thermopile sensor. Image processing techniques are used to try and isolate the heat signatures of a human while filtering out non-human heat sources.

The data used for this project is collected from a thermopile sensor sold by ROL Ergo AB. This sensor was placed in the ceiling above an office table and recorded the heat signatures of up to four people sitting around this table (see figure 1). Two meetings were recorded with this setup, where different permutations of four people sat at the table, as well as no people. The data collected from this sensor was collected through serial port to a computer and saved as a comma separated text file. This data was then processed using OpenCV v3.4.3 (C++).

Data for a total of 14 scenarios was used (different permutations of up to 4 people). In each scenario the thermopile sensor took a number of snapshots through the duration of the meeting, these snapshots will henceforth be called *frames*. Within each frame, 64 data points are collected, corresponding to each pixel of the 8x8 thermopile sensor. Because each frame only contains 64 data points, building an image of the data results in an 8x8 image which, in its raw form, is not very human interpretable (see figure 2). A number of image processing techniques are used to both make the image more interpretable and to make it easier for the edge detection to detect human heat signatures.

Figure 1: Placement of sensor

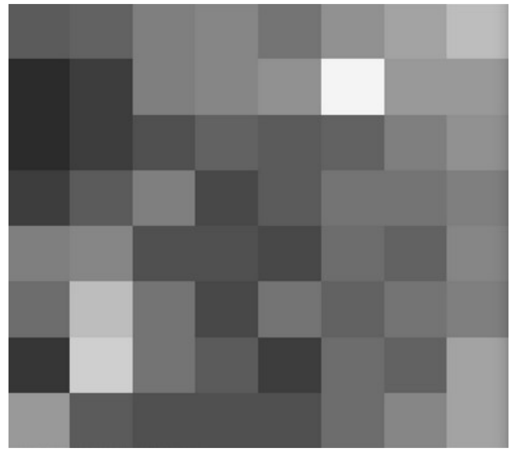

Figure 2: The raw data from the sensor as an image

The data from the thermopile sensor was processed in the following steps, each step will be explained in detail below:

1. Calculate background filter
2. Filter frames
3. Scale up frame and second filter
4. Edge detection and tracking
5. Combine track markers and processed images

2.1 Calculate background filter

In order separate human heat sources from non-human heat souces, the raw data is normalized and then the background noise is calculated for a scenario without people. This is done by taking the mean and standard deviation of each pixel through each frame. This means that, for each pixel, the valuie of that pixel is summed for all frames and then divided by the number of frames for that scenario. The standard deviation is also calculated.

2.2 First filter of frames

A pixel threshold is created with the mean and standard deviation calculated from the previous step. Each pixel for a frame is compared to this threshold and if the pixel value for the frame is below the threshold it is set to 0, otherwise left as is. This separates heat sources from the background noise. Because the data is normalized from the previous step, all the pixel values are also converted to an 8-bit value for easier handling in OpenCV.

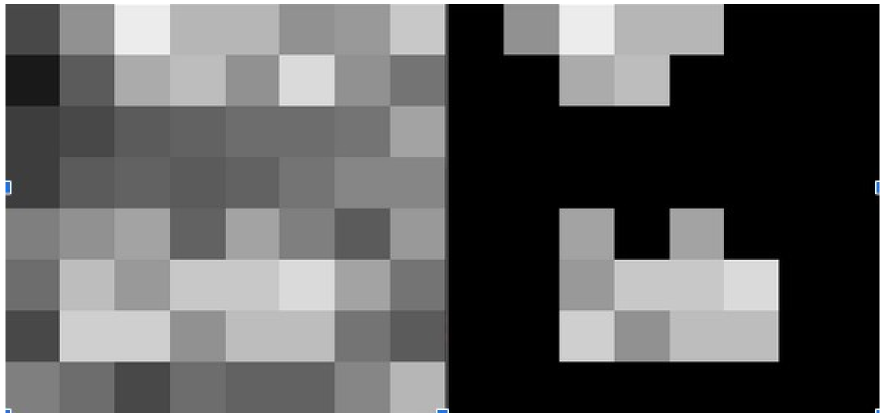

Figure 3: Raw data to the left, data after filter to the right

2.3 Second filter and up-scaling of frames

To get a bit more information to work with, the frames are scaled up using image pyramids to a 32x32 image. A second filtering is done where only pixel that has a non-zero value for longer than three frames in a row are kept, otherwise the pixel is set to 0 for all instances where it is non-zero less than three frames. This is done to remove any quick flashes of noise that remains after the first filter.

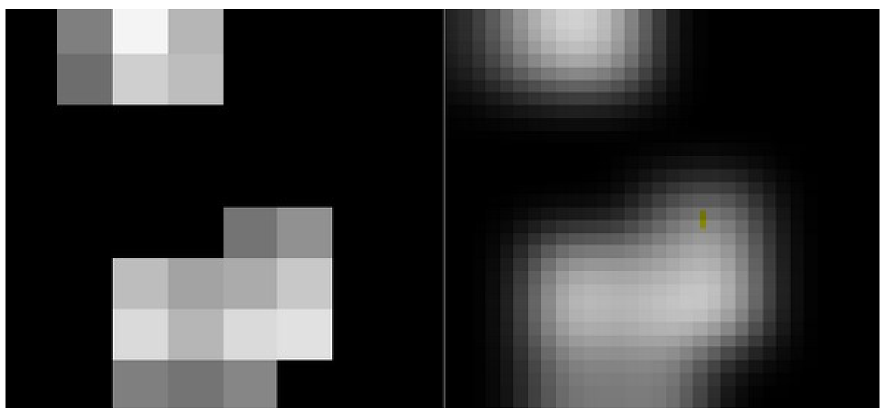

Figure 4: Frame after first filter on the left, frame after image pyramids and second filter on the right

A second pixel threshold filtering is also done to reduce the amount of low value pixels at the edges of the up-scaled heat signatures. This also reduces the size of the heat signatures slightly.

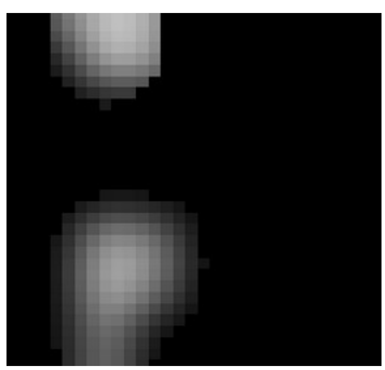

Figure 5: Frame after second pixel threshold

2.4 Edge detection and tracking

In preparation for the edge detection, the frame is converted to a binary image. This is done by set all non-zero pixels to the highest value (255) so that the edge detection only detects one edge. Canny edge detection is used to get the contours of the binary image. From the Canny edge detection, tracking markers are build from the position and size of the contours from the Canny edge detection. These markers encapsulate each heat signature.

Figure 6: Binary image

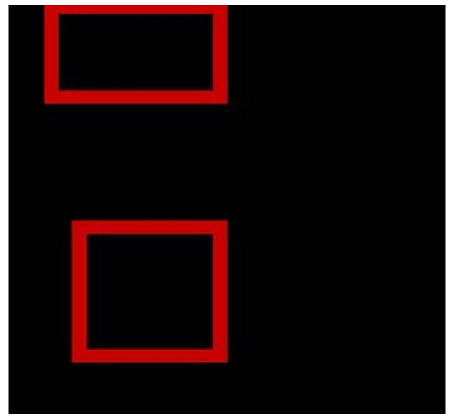

Figure 7: Tracking markers from edge detection

The number of participants tracked is calculated by the number and size of the tracking markers. If a tracking marker is above a certain threshold, the marker will count the heat signature as two people. This threshold is calculated by taking the mean size of each single person heat signature and mean size of each two person heat signature. Additional manual tweaking is also done.

2.5 Combine tracks and processed images

When constructing the resulting image that is shown to the user, frames from the secondary filtering (before the image is converted into a binary image) is taken and the contrast is increased to make the heat signatures a bit more clear for the user. The Tracking markers are combined to this image and the resulting tracking markers will follow the heat signatures. A number is also added to the image to display how many people the algorithm has detected for that specific frame.

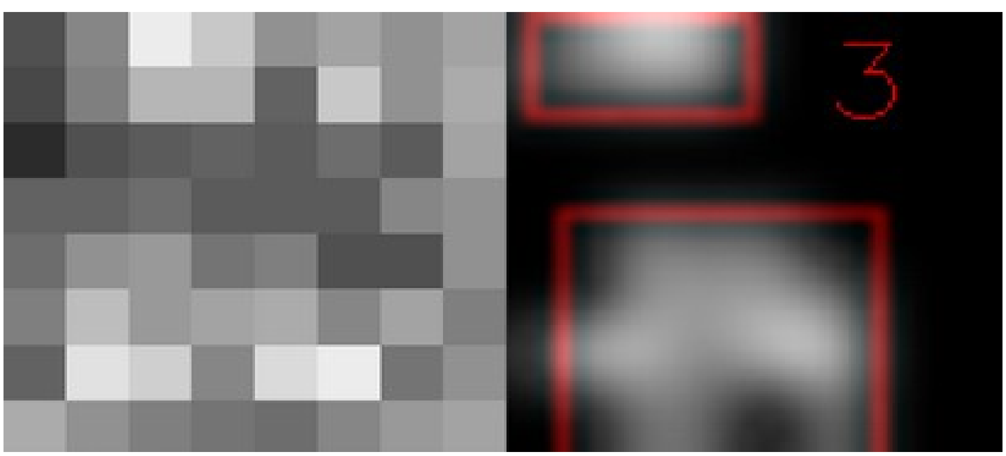

Figure 8: Image of the raw data on the left, the resulting image after processing and track markers are added on the right

The rightmost image in figure 8 shows the final results of the algorithm. Note that the larger heat signature is correctly classified as two people.

3 Results

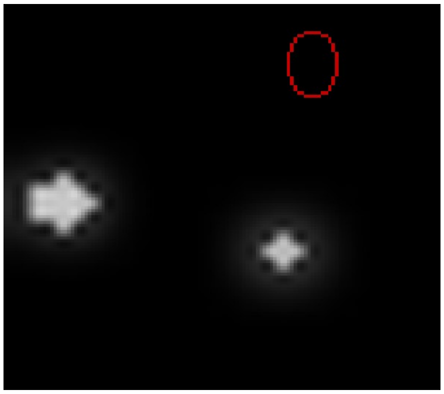

Figure 9: No people in the meeting.

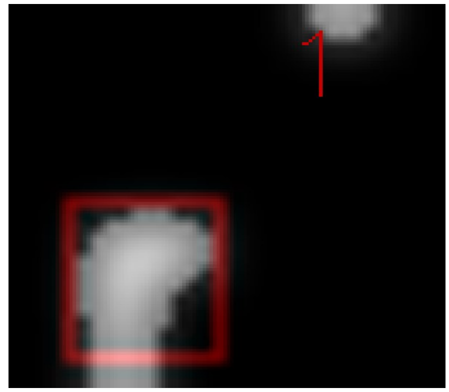

Figure 10: One person in the meeting.

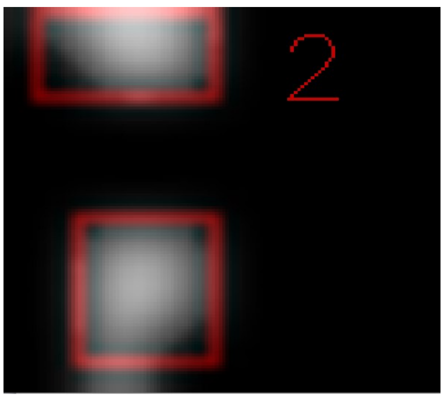

Figure 11: Two people in the meeting.

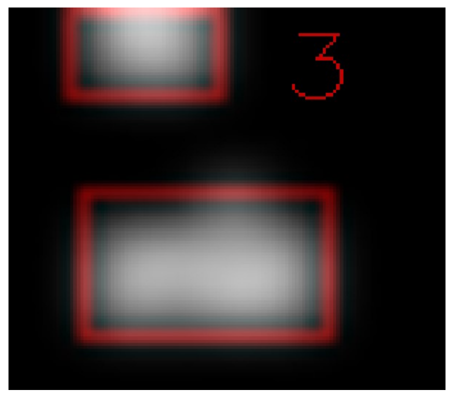

Figure 12: Three people in the meeting.

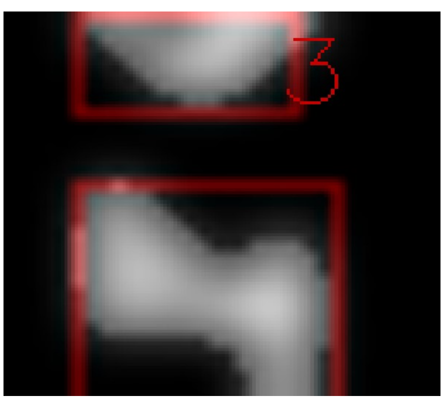

Figure 13: Four people in the meeting

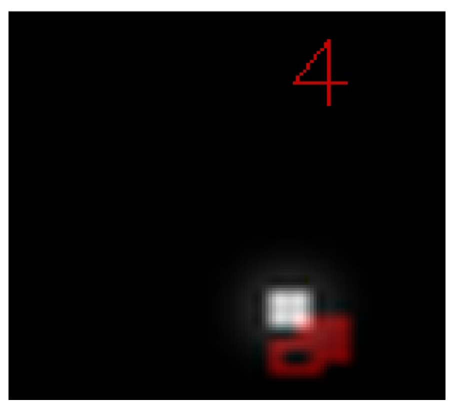

Figure 14: No people in the meeting

In figure 9 there is no people in the meeting, and we see that the algorithm do not detect any human heat signatures, even though there is noise. In general, the algorithm correctly detects and tracks up to 3 people. However, when there's four people in the meeting, as seen in figure 13, it does not detect all four people. This could be due to the fact that the heat signatures of the people on the top were generally smaller than the bottom one, which could mean that the size of the top heat signatures are too small to trigger the "two people" threshold. In figure 14 we can see a scenario where it doesn't work. Some of the meetings had a large amount of thermal noise which gets picked up by the algorithm. In this case it picks up four heat signatures.

4 Discussion and future work

While you can successfully identify a human heat signature from the 8x8 image data from the thermopile sensor, the low resolution of the data means that there is a low amount of information to use. Thermal noise in the environment has a large impact on the data, this could be seen in the data when the sun was shining on the table and its heat signature stretched across half of the frame. Additionally, having other heat sources in the form of, for example, coffee cups will get picked up by the sensor and algorithm. There are techniques that could potentially mitigate these concerns. You could look at how the heat signatures move to maybe distinguish between a living and non-living heat source. You could enforce a calibration mode of the sensor where you let the sensor system calibrate a background filter with an empty room before a meeting, in this calibration mode it could log the "empty room" value per pixel and use this to "zero" the background of the image. Although this would only work if the human heat signature is warmer than the "empty room" value.

In addition, because of the low resolution of the sensor, counting participants presents a challenge. Training a classification model on the size of the heat signature would be a logical next step from this project. You could then classify the sizes and intensity of the heat signatures to distinguish between non-person (e.g. coffee cup), one person or two persons depending on the size of heat signature. Another approach could be to try and slice large heat signatures into smaller ones.

References

[1] Yousef [Al horr], Mohammed Arif, Martha Katafygiotou, Ahmed Mazroei, Amit Kaushik, and Esam Elsarrag. Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature. *International Journal of Sustainable Built Environment*, 5(1):1 – 11, 2016.

[2] Luis Ignacio Lopera Gonzalez, Marc Troost, and Oliver Amft. Using a thermopile matrix sensor to recognize energy-related activities in offices. *Procedia Computer Science*, 19:678 – 685, 2013. The 4th International Conference on Ambient Systems, Networks and Technologies (ANT 2013), the 3rd International Conference on Sustainable Energy Information Technology (SEIT-2013).