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THERMASEC

Building the future of fire detection

EE464S Senior Design

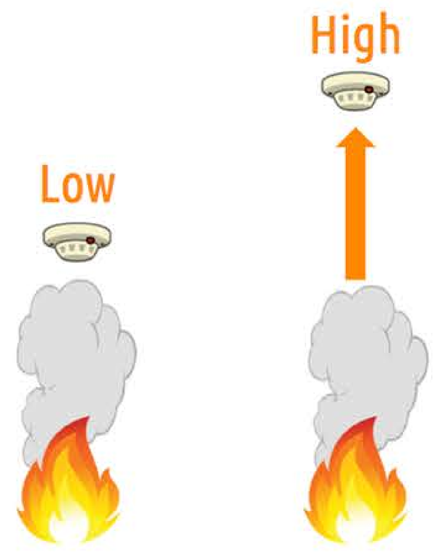
Problem with traditional detectors

Fires double in size every 30 seconds

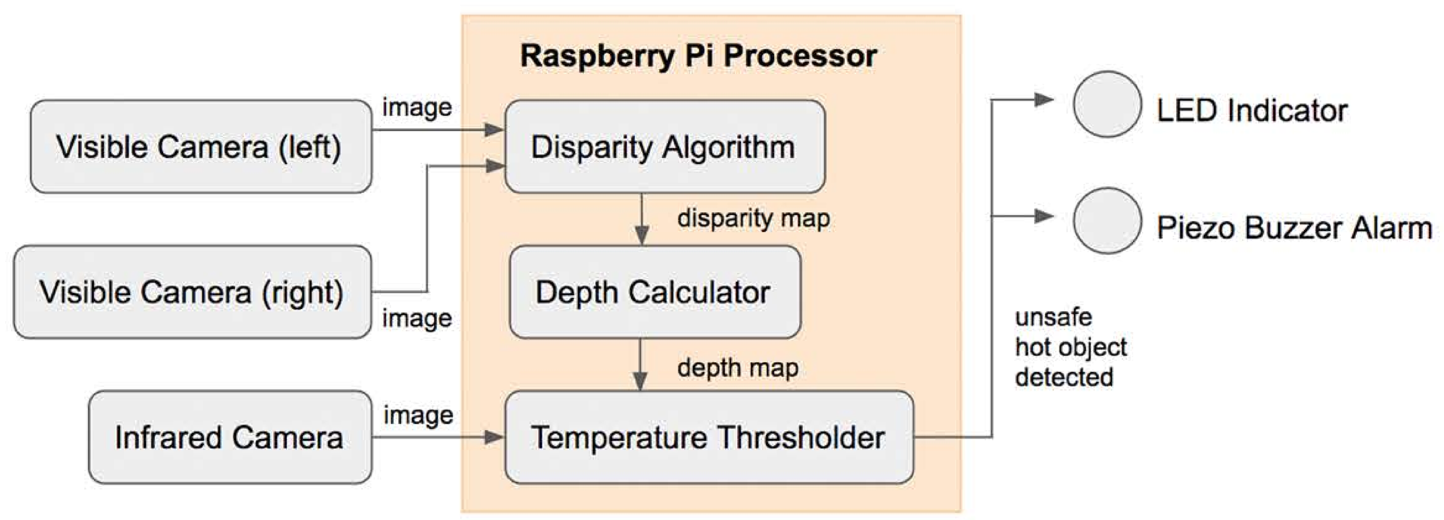
46% of fires take 5 or more minutes to be detected by traditional smoke detectors

Response times are significantly slower for detectors on high ceilings

Many detectors are expensive and have high cost per square foot of coverage

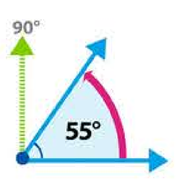


Block diagram of design



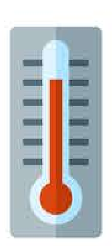
Design requirements

Detector must have detection times of 5 seconds or less for 15 to 50 ft ceilings for competitive market advantage



Need a working Field-of-View (FoV) of 55° for visible and IR cameras. This field of view provides us with competitive square foot coverage compared to other detection methods.

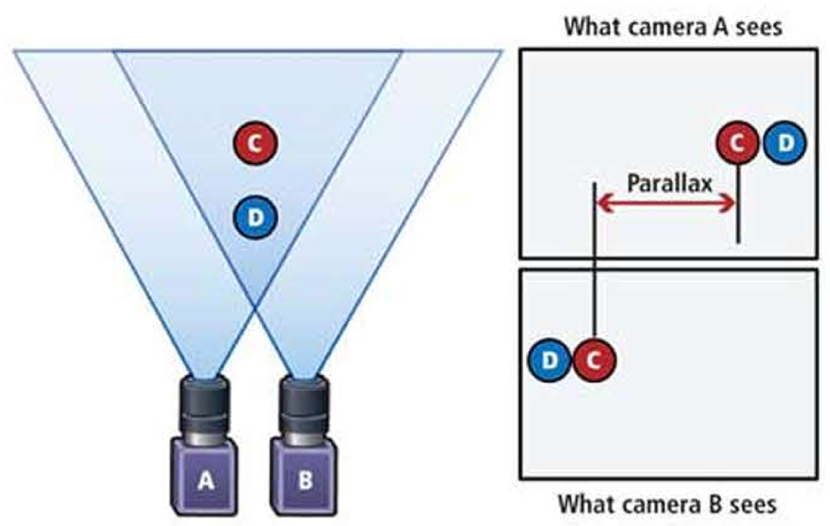
Must be able to detect potential fires and unsafe heat zones that have an area greater than 25 cm^2 and an actual temperature value above 250° F



To ensure that our detection software provides optimal detection, we need temperature and distance measurements (from our sensors) to be accurate within +/- 10° F and +/- 50 cm respectively

Summary of design solution

Our design solution will use visible cameras to approximate distances in the scene. These distances will be used to correct for temperature fall-off in the IR images.



example of parallax view

Similar to how human eyes work, our visible cameras are able to approximate depth of objects in the scene. Using basic geometry, our system calculates the disparity between corresponding pixels in the scene, and maps the disparities to depth-from-the-detector values.

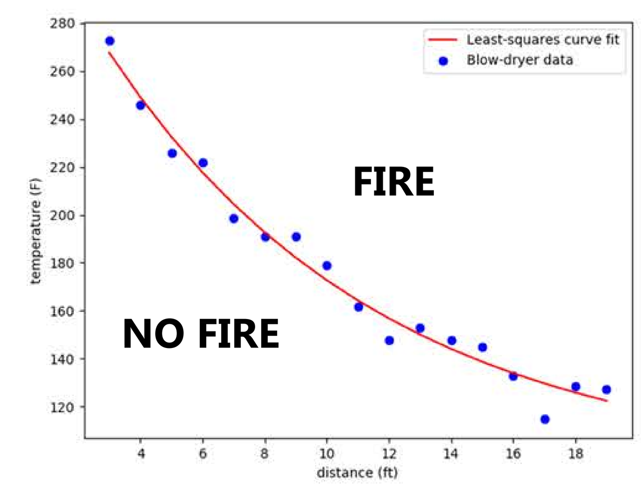
Once we obtain the depth map from the visible cameras, we can combine the data with our IR image to have an image with temperature and depth values at every pixel. Then we use a thresholding detection function to detect if an unsafe heatzone is present.

visible image

This threshold function adjusts our IR image with depth to predict if the actual temperature of each pixel in the scene is above or below 250° F. Temperatures above 250 are deemed unsafe and have high potential to cause a fire or property damage.

stereo depth map

Technical details



IR temperature fall-off

This graph shows the temperature fall-off for hot objects measured by the IR camera at varying distances. We measured a constant heat source of 250° F at 1ft increments from the camera along a fixed axis. Then we fit an exponentional regression the data points to calculate our threshold function.

$$T_{threshold}(x) = c * e^{-ax} + b$$

As an input, this function takes in a distance-from-camera (depth) value. The output is the fall-off temperature along the regression threshold. If the fall-off temperature values in the IR image are above this threshold, the detector is triggered.

```python
while True:
    # Capture visible & IR images
    img_left, img_right = capture_visible()
    img_ir = capture_infrared()

    # Calculate disparities and convert to depth values
    img_disp = calculate_disparity(img_left, img_right)
    img_depth = convert_to_depth(img_disp)

    # Align the IR image & depth Map image to fit each other
    img_depth, img_ir = align(img_depth, img_ir)

    # Use IR (temperature) and depth values to check if any pixel
    # in the scene is above an unsafe temperature threshold value
    if is_above_threshold(img_ir, img_depth):
        turn_on_alarm()
```

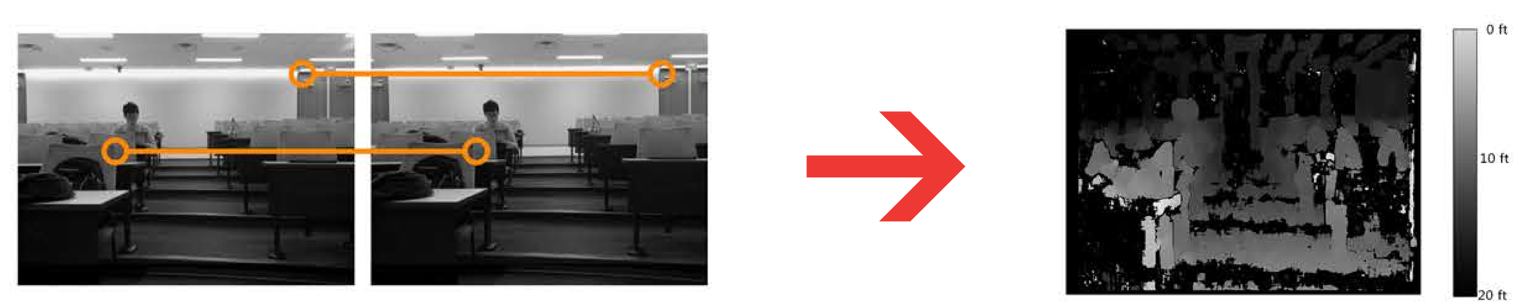
main event loop for detection

Our detection software was primarily written in Python 3. The program repeatedly cycles through image calculations and temperature thresholding. Each detection cycle takes approximately 2 seconds from start to end.

Software module testing

Stereo Vision / Disparity Test

Are key objects/planes distinguishable in the disparity map? This test involves setting the 2 visible cameras on a fixed axes and taking simultaneous pictures. Through the StereoSGBM algorithm, we compute a map of distances between corresponding pixels.



Depth Conversion Test

For our design we needed to check that depths were accurately estimated by the system. We placed objects at varying distances between 5ft and 25ft. Next we verified that the depths of each object was accurate within 25 cm of the actual depth

Align Images Test

Take simultaneous images using the IR and visible cameras. Compute the disparity map, and then the depth map. Align the images so that objects in the scene are mapped 1-to-1. Repeat the process 4 or more times to ensure consistency

Full system application testing

Controlled Heat Source

Can our system detect a basic heat source near the threshold temperature? To perform this test, we have tested our system with a heat gun at various distances within the range 5ft to 20ft and various temperatures in the range of 180 degrees to 240 degrees. The true temperature of the heat source was confirmed with a secondary FLIR thermal imaging camera at close range.

Real-World Fire Test

How does our system work in a real-world environment? Based on our results, our detection design is able to meet our design requirements successfully in a scenario with an actual fire. However, the fire must be unoccluded by other objects in the scene.