Detection of intruders in warehouses using Infrared based Thermopile Sensor Array

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Abstract: The infrared thermopile array sensor detects the object at motion based on the infrared radiation radiated by the human body. The infrared radiation radiated is related to the human body temperature. Temperature difference exist between the human body and room temperature. Temperature values are obtained as the person approaches the field of view of a sensor. In this paper a mechanism is developed to track the moving object based on their centroid values. From the each temperature frame the foreground region is extracted and from the obtained centroid value of each region, the object is tracked by representing the bounding box across the tracked foreground region.

1. Introduction

Thermopile sensors are used to measure the temperature of an object. These are the contactless temperature measurement devices [1]. In a thermopile sensor multiple thermocouples are connected in series. To increase the output voltage produced by the single thermocouple, the “n” number of thermocouples are connected in series. This forms a single thermopile element. The thermopile sensors are extremely sensitive and show very fast response. The infrared radiation wavelength used for the human detection range is from 8-15 µm which undetectable by the human eyes. Only the specific information like motion, position and area of hot or cold objects are being required in some infrared applications. Compared to the single thermopile element sensor the thermopile array sensor is highly advantageous because these sensors have the capability to detect even the object at stationary. In the usage of these sensors to detect and track the moving object, the concept of centroid of an object is used. When an object that emit infrared radiation is at motion each time its centroid (centre of mass) also changes. Each time centroid of an object is extracted from the obtained temperature values. The method used is in this paper being able to detect and track the multiple foreground regions. The work is mainly focussed on developing an algorithm to detect the foreground region. Multiple temperature values obtained from a sensor of moving object are interpolated using an algorithm and then the foreground regions are extracted from the resulting image. Each time from the resultant frame the centroid is being tracked. The obtained centroid determines the presence of intruder in the warehouse.

2. Need for Research

To develop the efficient intruder detection technique in a warehouse using infrared thermopile array sensor using MATLAB.
3. Steps used in the detection and tracking of an Intruder in a warehouse

The approach used in the detection and tracking of moving object based on the temperature values include following steps:

3.1 Person Approaching Field of View of a Sensor:

When a person moves towards the sensor in its field of view, the person will be sensed by the sensor. Infrared thermopile array sensor senses and detects only those object that radiates infrared radiation. The sensor has got its own field of view (vertical and horizontal) and recommended detection distance. There is a difference between the room temperature and temperature of an object (human). So the temperature values sensed by an object are obtained and used for detection purpose. The Figure 1 represents the flow used in the detection of moving object based on temperature values by the infrared thermopile array sensor.

![Figure 1. Flow Diagram to Detect the Intruder in a Warehouse using Infrared Thermopile Array](image)

3.2 Temperature Mapping

The temperature values of detected object obtained from the sensor are mapped into specific frame. The mapping is done on the basis of arrangement of thermopile array in a specific grid format. For example if the thermopile array sensor consists of 64 thermopile elements arranged in a 8*8 grid format, the temperature values obtained from the sensor are arranged in same grid format.

3.3 Interpolation Algorithm

From the obtained temperature values of a moving object, it’s not possible to obtain the region traced by the sensor. So in order to obtain the smooth trajectory for a path travelled by the human specific algorithm is required. The method used is passing the frame of temperature values into an Interpolation Algorithm [2], [3]. If in a frame the specific temperature values are treated as pixels, the interpolation algorithm increases the resolution of the frame.

3.4 Segmentation of a Frame

After increasing resolution of the frame using the interpolation algorithm the foreground region in the frame is extracted using the threshold method. The threshold value is selected by using the average of maximum and minimum intensity of pixels in the frame [4]. The equation used to select the threshold value is being given by:
\[ T = \text{mean} \left( \frac{\text{max}(f) + \text{min}(f)}{2} \right) \] (1)

Where \( f \) the frame of pixels obtained after interpolation and \( T \) is the threshold value being selected. The value of the pixels below threshold is being made zero. After the threshold method two regions are created. The region extracted above threshold is the desired foreground region and region below threshold is the background.

3.5 Connected Component Analysis

In object detection and tracking, in order to compute all the active regions in a frame connected component analysis is used [5], [6]. From the frame the active regions are connected using the local neighborhood that can be either 4 or 8 pixel neighbourhood. The unique ID is being provided to each pixels if it falls in the foreground region and the value will be 0 for the background pixels.

3.6 Extraction of the Features in the Foreground Regions

After the connected component analysis, moving object is being tracked by using the centroid values. After obtaining the centroid values each object is tracked from these centroid values showing a bounding box across the detected area. As the object changes its position, its centroid will also get changed. The change in the position of an object will be shown by the bounding box.

4. Results

When the intruder moves in the field of view of a sensor each time the infrared thermopile array sensor sense the intruder. The obtained temperature values are interpolated using the Interpolation Algorithm. The foreground region is extracted using the threshold method. The connected component analysis is being done, centroid is being obtained and object is tracked by drawing bounding box across the detected region. After the processing of this frame next frame temperature values are read and same processing steps are followed. The centroid based moving object detection involves following steps:

1) Read the frame of temperature values.  
2) Interpolate the frame using the Interpolation Algorithm.  
3) Segment the foreground region using threshold method.  
4) Connected component analysis and labelling all the active regions obtained using unique ID.  
5) Extracting the centroid, area and bounding box dimension of the active region.  
6) Representing the detected region from the centroid using the bounding box.  
7) Go to step 2) to track next frame of temperature value.

From the each frame read the tracked region is being shown by the bounding box. The larger area in the frame corresponds to the detected area of the human movement, while smaller area corresponds to the other parts of the human got sensed by the sensor. Body temperature values of a human is being detected by the sensor when the person moves. Tracking from the frames of temperature values are done using the centroid method. The tracking is done using the real time temperature values of a human.

The detection and tracking of moving object based on centroid method is shown in the Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8.
Figure 2. First Detected and Tracked Foreground Region

Figure 3. Second Detected and Tracked Foreground Region

Figure 4. Third Detected and Tracked Foreground Region

Figure 5. Fourth Detected and Tracked Foreground Region

Figure 6. Fifth Detected and Tracked Foreground Region

Figure 7. Sixth Detected and Tracked Foreground Region
The centroid in each detected region is shown in the frames using the cross mark. The path traced by the human in the X and Y coordinates is shown in the Figure 9.

5. Conclusion
The detection and tracking of a human using the infrared thermopile array by centroid method is the efficient one. Change in the position of the centroid determines change in the movement of an intruder. The infrared thermopile array include wide number of application like stationary, moving object detection, detecting the direction of the movement and many more. The other sensors like pyroelectric sensor, or single element thermopile sensor will detect the object at motion.

But the thermopile array sensors detects the moving object, stationary object, measures the temperature, direction of movement and also provides thermal image. So these sensors can be used in wide range of application compared to pyroelectric and single element thermopile sensor. In this paper work on moving object using the centroid method to detect an intruder is being done. In the future work can be extended to detect the direction of movement of a human.

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