Prototype Design of a Human Activity Recognition and Fall Prediction System Based on Infrared Array Sensors

Nishat TASNIM NEWAZ[†a)], ***Nonmember and*** **Eisuke HANADA**[††b)], ***Member***

SUMMARY The development of a prototype system for human activity recognition and fall prediction is crucial to addressing the safety concerns of elderly persons. Utilizing surveillance cameras and computer vision to detect falls presents an ideal alternative to existing systems, ensuring protection for anyone within the camera's monitoring scope. However, privacy concerns regarding the use of surveillance cameras for this application remain a significant consideration. In this paper, we present the design of our prototype for such a system that utilizes an infrared array sensor to capture relevant data and that does preliminary mapping of multiple interpolations. The system compares the actual image and the mapped image, providing results based on the person's body temperature. When a person is detected, the system can determine their posture, distinguishing between sitting, standing, lying, or falling.
key words: *Prototype, Infrared array sensor, Interpolation, Mapping image.*

1. Introduction

Over the past few decades, there has been significant progress and advancement in the field of automatic vision systems. Standard imaging devices have relied on visual cameras that capture grayscale or RGB images using visible light. However, these cameras come with certain drawbacks. The colors and visibility of objects are reliant on an external light source, such as the sun or artificial lighting [1]. To reduce the number of cameras required, a wide range of options are available, such as fish-eye lens cameras [2] or omnidirectional cameras [3, 4]. Nevertheless, all these surveillance vision systems encounter difficulties when there are changes in ambient light, whether transitioning from day to night or vice versa. As a result, the conventional task of digitally analyzing color images in smart surveillance becomes incredibly challenging and unsuitable for detecting faint objects in low-light conditions. An alternative approach involves employing a wearable sensor that incorporates acceleration and inclination sensors to automatically recognize motion and subsequently trigger an alarm [5]; however, this type of system is ineffective if the individual forgets to wear the sensor. A potential solution lies in utilizing automatic surveillance systems based on vision-based technologies. A recent development in this field is the use of thermal cameras to detect human movement or to identify instances of machines overheating. Thermal cameras offer the advantage of detecting and visualizing heat signatures, enabling non-contact temperature measurements and enhanced surveillance capabilities in various applications. Because they can capture and reveal personal information such as body heat patterns, the use of thermal cameras raises privacy concerns. Proper safeguards and regulations should be in place to protect privacy when implementing thermal camera technology. In this paper, we propose a system in which a thermal camera can categorize falls by whether the person is standing, sitting, lying, or falling. It is aimed at people living alone or for people in situations that have poor lighting. Because a thermal camera does not capture pictures, there are no privacy issues. Also, because thermal cameras can be made waterproof, the system can be used in washrooms or bathrooms. Herein we report the development of our prototype system and present an analysis with various interpolations that show its efficiency.

2. Related Work

There are many papers about human activity recognition with thermal cameras. Some of them are described briefly below. The authors of the paper [6] proposed an approach for detecting falls that involve the combination of a 3D convolutional neural network and an auto-encoder. A neural network extracts video features and an auto-encoder models normal behavior, yielding lower errors for normal than fall videos. Validation and field tests affirm its efficacy in fall detection and privacy-preserving image sensing. The goal of [7] was to confirm the effectiveness of a smartphone-based infrared (IR) camera by comparing it to a high-end IR camera specifically designed for evaluating diabetic foot conditions. A new approach called the Spatio-temporal Residual Autoencoder (SRAE) model is proposed in [8] as an unsupervised fall detection system for elderly persons. This model utilizes deep learning techniques to identify instances of falls. Both regular activities of daily living (ADL) and fall actions are used to evaluate the proposed model. Paper [9] presents the introduction of two uncomplicated and rapid detection algorithms into an economical thermal imaging surveillance system. This system serves the purpose of not only monitoring the operations of various machinery and electrical equipment within a factory site but also detecting trespassers in low-light conditions. In paper [10], the authors present the identification of falls as a problem of anomaly detection and propose the use of autoencoders for this task. They also introduce a fresh approach called the cross-context anomaly score for their calculation of anomaly scores. The

[†]Graduate School of Science and Engineering, Saga University, Japan
[††]Faculty of Science and Engineering, Saga University, Japan
a) E-mail: 22805191@edu.cc.saga-u.ac.jp
b) E-mail: hanada@cc.saga-u.ac.jp

authors conducted experiments using various autoencoder methods on a dataset that captures both everyday activities and falls using a non-intrusive thermal camera. The findings from these experiments demonstrate that Convolutional LSTM autoencoders exhibit superior performance to convolutional and deep autoencoders when it comes to detecting falls that have not been encountered before. A straightforward algorithm for detecting fainting events in a home-alone situation is proposed in the paper [11]. It is integrated into a precise temperature measurement thermal imaging surveillance system. The algorithm allows for the detection of fainting events in both favorable and challenging lighting conditions. In the event of a person fainting, the system activates an alarm signal that remains active until the operator takes the necessary rescue action and manually resets the system. A robust walking fall detection system has been created [12] that successfully identifies and analyzes fall events as distinct activities, without the need to detect or specify external parameters like floor plane coordinates. The algorithm effectively detects walking falls while minimizing false positives caused by non-fall actions such as forcefully sitting on a chair, lying on the floor, or crouching down. The researchers in [13] used thermal array sensors to collect useful data that can be used with machine learning to do human activity recognition.
Furthermore, while some studies like [6] and [10] utilize complex neural networks and autoencoders for fall detection, our prototype system adopts a novel approach that utilizes an infrared array sensor. While others mainly focus on spotting falls [7, 8, 9], our prototype looks at a wide range of movements like sitting, standing, or falling, giving a fuller picture of what people do. Unlike complex methods, we use an Infrared Array sensor and smart mapping to understand actions, not just pictures. This sets us apart.

3. Methodology

Infrared (IR) array sensors, also known as IR imaging sensors or thermal imaging sensors, are devices used to detect and capture thermal radiation in the infrared spectrum. They work by converting the heat energy emitted by objects into electrical signals that can be processed and interpreted to create images or measure temperature variations. In this work, we used a Panasonic AMG8833 IR array sensor that has 8*8 pixels of IR sensors. We can plot the thermal values in front of the sensor and assume which positions have thermal values. This can be used to shape a human object in front of it and the status of that object. This method can be interpolated to create efficient images and predict human activity and accidents. The prototype device used Raspberry Pi 4b as the processing unit. It has a 64-bit quad-core Cortex-A72 processor and 8GB LPDDR4 RAM. A simple circuit diagram of Raspberry Pi and AMG8833 is shown in Figure 1.

After getting the 8*8 pixels of IR array sensor data, we need to do interpolation so that we can recognize the human object more precisely. Image interpolation is a technique used to estimate pixel values in an image at positions that are not explicitly provided. Interpolation is needed to fill in missing data or estimate values between known data points. It allows for resizing images, estimating missing values in datasets, enhancing image quality, and creating smooth curves and surfaces for visualization purposes. Interpolation algorithms can be classified into two categories: adaptive and non-adaptive. Adaptive methods adjust their approach based on the specific data being interpolated, while non-adaptive methods treat all pixels uniformly, without considering their individual characteristics. Non-adaptive interpolation methods treat all pixels equally, without considering any variations or specific characteristics among the pixels. The process involves applying a fixed interpolation algorithm, such as the nearest neighbor, bilinear, or bicubic, to estimate the missing pixel values based on the surrounding known pixels without considering any specific characteristics of the data [14, 15].

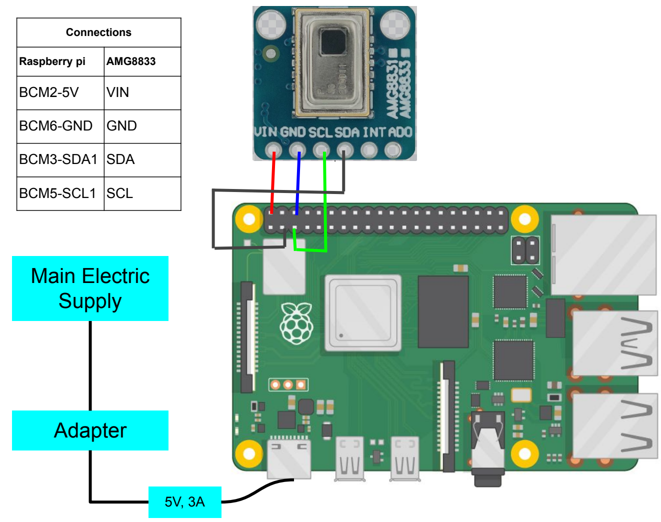

Fig. 1: Prototype Circuit Diagram.

The determination or estimation of the value of $f(x)$, or a function of x, from certain known values of the function. If $x_0 < \ldots < x_n$ and $y_0 = f(x_0), \ldots, y_n = f(x_n)$ are known, and if $x_0 < x < x_n$, then the estimated value of $f(x)$ is said to be an interpolation [16]. Interpolation is essential for accurate analysis, prediction, and generating visually appealing results in various fields such as science, engineering, and computer graphics. The process for capturing the temperature values by pixels and interpolation is mentioned in Algorithm 1.
Now, we need to do the following:

- Store the pixel-wise temperature values in CSV files for different positions.
- Train machine learning algorithm with different position values.
- Train machine learning algorithm with different position-changing values.
- Detect the positions (seating, walking, standing,laying).

Algorithm 1 AMG8833 IR array reading with Raspberry pi and Interpopation

```
Initialization of libraries and Sensor
Read data with i2c port 68 or 69 from AMG8833
Read 64 pixels of temperature
Set figure size and plot the temperature values in the pixels
Set colorbar and plot different temperature in different colors
Start process for original resolution to Interpolation
original pix.res = (8,8) set to xx,yy
new image: zz = np.zeros(pix.res) set to grid.x,grid.y
multiplier for interpolation: pix.mult = 6
interp.res = (int(pix.mult*pix.res[0]),int(pix.mult*pix.res[1]))
procedure INTERP(Z.VAR)
    f = interpolate.interp2d(xx,yy,z.var,kind='cubic')
    return f(grid.x,grid.y)
end procedure
grid.z = interp(zz)                                    ▷ interpolated image
for sensor.read.temp(pix.to.read do
    T.thermistor = sensor.read.thermistor()            ▷ read thermistor temp
    fig.canvas.restore.region(ax.bgnd) ▷ restore background (speeds up run)
    im1.set.data(np.reshape(pixels,pix.res)) ▷ update plot with new temps
    ax.draw.artist(im1)                                ▷ draw image again
    fig.canvas.blit(ax.bbox)               ▷ blitting - for speeding up run
    fig.canvas.flush.events()                          ▷ for real-time plot
    print("Thermistor Temperature: 0:2.2f".format(T.thermistor))
    Save the raw temperature pixelValues data to CSV files
end for
```

- Detect the normal position changing interval times.
- If an abnormal interval appears then it may be a candidate for accidental movement or fall.

4. Results

The prototype of our system is shown in Figure 2. A Raspberry Pi 4 is connected to an AMG8833 thermal sensor. The prototype is placed horizontally on a table.

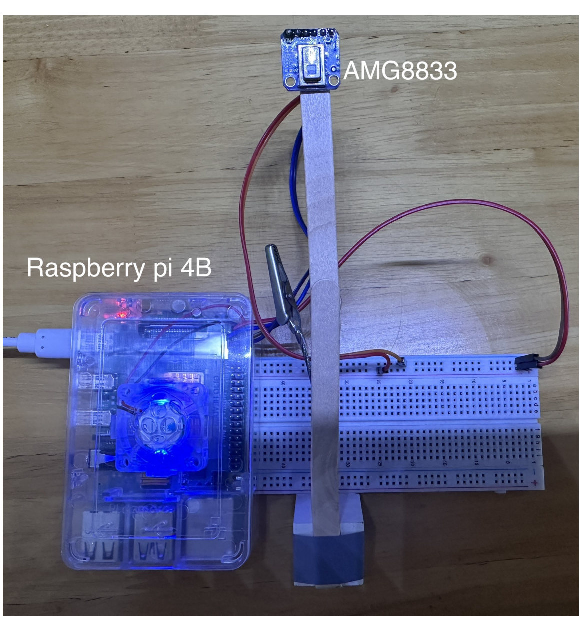

Fig. 2: Preliminary prototype

In figure 3, preliminary mapping of the system is shown where the interpolation is varying 1,2,3,5,8,10, and 50. We can see that when the interpolation is 1,2,3, and 5 the picture is not clear. The depiction of the human temperature becomes clearer with increasing interpolation. In Figure 4, interpolation 10 gives the best result when compared with the real picture. In interpolation 50, the pixels are so smooth that the detection is not clear again. Also, if the interpolation is up to 50, the 8x8 pixels turn out 400x400, which can increase the complexity of the machine learning algorithm as well as create pressure in the Raspberry Pi.

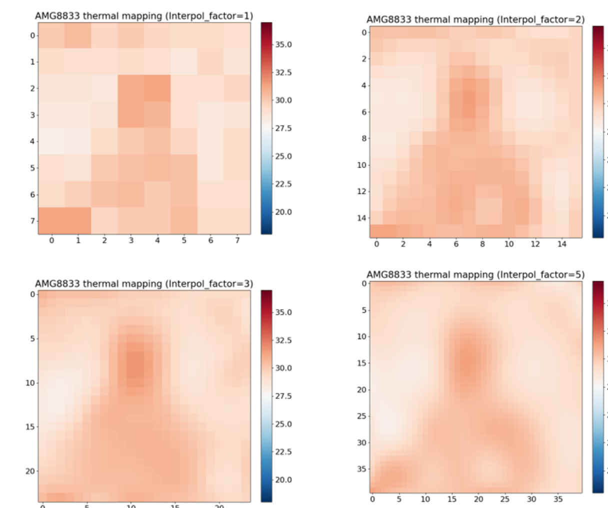

Fig. 3: Mapping of interpolation=1(left),2(right),3(lower-left),5(lower-right)

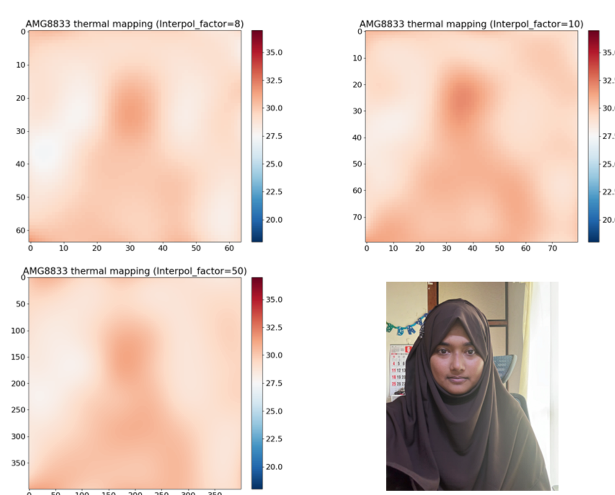

Fig. 4: Mapping of interpolation=8(left),10(right),50(lower-left),(Real picture)

5. Conclusion and Future Work

The proposed prototype design for human activity recognition and fall prediction with an infrared array sensor shows

promise in addressing the safety concerns of elderly persons. By utilizing thermal imaging and advanced algorithms, the system aims to accurately recognize activities and predict falls, which would contribute to improved assistance and reduced response time in case of emergencies. In this paper, we developed a prototype with which mapping is shown in various interpolations. The system compares a real picture with the mapping picture and shows a result from the person's body temperature. Once it detects a person, it can detect whether the person is sitting, standing, lying, or falling.
Our future research will be to detect falls with this thermal system by applying machine learning (ML) algorithms. For that, we are making datasets to train the model and after training, we will apply ML algorithms for detecting the falls. Our prototype stands out by using an infrared array sensor for fall detection, capturing a broader range of movements like sitting and standing. Unlike complex methods, our approach focuses on understanding actions through smart mapping, setting us apart from others.

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