LSTM-Based Human Fall Detection using Thermal Array Sensor

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***Abstract*—Accidental fall may lead to numerous serious and deadly injures. Existing fall detection systems mostly use cameras and are considered a privacy-intrusive approach. Thermal array sensors are considered a privacy-friendly device that does not raises discomforts for users. In this study, we simulate a fall detection system using a thermal array sensor with three different algorithms: CNN, LSTM, and CNN-LSTM. Our result shows that LSTM has the best accuracy among other algorithms by 99.96%.**

***Index Terms*—CNN, CNN-LSTM, Fall detection, LSTM, thermal array sensor.**

I. Introduction

Accidental fall can lead to serious injuries and health problem, especially for people living alone. The number of older population suffered from emergency health issues from fall is 2.8 million [1]. This emerges the need for a fall detection system, especially for elderly people living separated from their relatives.

Various fall detection systems have been developed in several studies, such as in [2], they developed a fall detection that uses camera as the data acquisition device. However, using a camera as data acquisition device is considered as privacy-invasive approach and therefore other system is developed to overcome this limitation.

In [3], they presented an emergency detection study using LIDAR sensor. As a cost-effective and efficient alternative to LIDAR sensor, we use thermal array sensor to detect human movement. Taramasco *et al* in [4] presented fall detection based on thermal array sensor which resulted in 93% of accuracy using Bi-LSTM method. Thermal sensor has proven as a privacy-friendly and convenient approach as it only generates data of temperature from the monitored room and does not require to be attached to the human body.

In this study, we developed a fall detection system using data generated from thermal array sensors and three types of deep learning algorithms, namely CNN, LSTM, and CNN-LSTM. Section II describes the system design used for this study and a basic introduction of the deep learning algorithm used for this study. Results and the evaluation of obtained performance are described in Section III. Finally, Section IV concludes this paper and suggestion for further research are presented.

II. System Design

We used a dataset consist of 32 columns and 216,784 examples. Each column representing a pixel value of measured temperature that were generated from OMRON D6T-8L-06 thermal sensor (1x8 pixels). In this dataset, fall movement is monitored along with the monitor of activity daily living (ADL). Hence, each row is labeled as fall or ADL based on the condition measured from the sensor.

To predict the fall event, we feed the data to a model trained using three different deep learning algorithms.

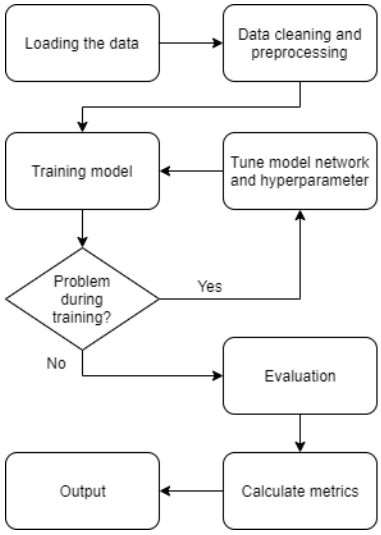

Fig. 1: Phases in fall detection system

Fig 1 describes the diagram block flows for fall detection. After loading the dataset, data is cleaned from 0, NaN, and null values. Then data is feed to the model after being preprocessed. In data preprocessing part, we perform feature scaling and dimension reduction using Min-Max scaling scikit learn [5]. Three different deep learning model is trained, namely CNN, LSTM, and CNN-LSTM. If the model does not show overfitting or underfitting characteristics, then the model is evaluated. Finally, output from the calculated metrics is obtained.

A. Convolutional Neural Network

Convolutional Neural Network (CNN) is a type of deep learning algorithm that uses a mathematical operation named

convolution to generate appropriate output feature maps from input data [6]. Generally, CNN works best with images as input data, but by using Conv1D CNN this approach is possible to be implemented on raw sensor data.

B. Long Short-Term Memory

Long Short-Term Memory (LSTM) is able to look back into previous data sequence to predict the next sequence. This is because LSTM has a memory cell which can empower it to store values that records information in overtime [4].

C. CNN-LSTM

Combination of CNN and LSTM is commonly used in fall detection system to eliminate the vision-related problems namely occlusion, image noise, incorrect segmentation, etc [1]. This approach will let the recurrent layer get precise information to determine the important elements that can be processed in temporal format [4].

III. Performance Evaluation & Result

In this section, we presented the obtained accuracy, precision, recall, and computing time of each mentioned algorithm to conduct fall detection.

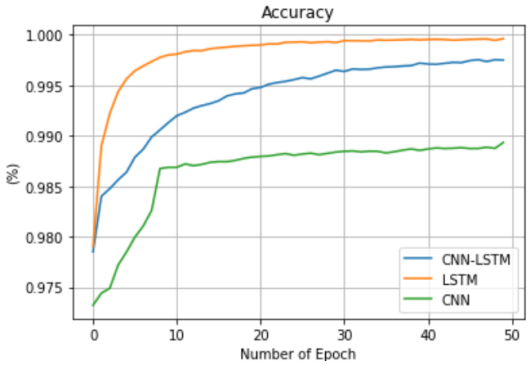

Fig. 2: Accuracy of CNN, LSTM, and CNN-LSTM

Fig 2 shows the accuracy of the respective models learned during each epoch. While all of the models achieve such promising accuracy result of more than 98%, LSTM achieved the highest result of 99.96%, followed by CNN-LSTM (99.74%) and CNN (98.93%).

TABLE I: Comparison of precision, recall, and computing time of mentioned algorithm

Algorithm	Precision	Recall	Computing Time (ms)
CNN	98.24%	99.8%	0.067
LSTM	99.87%	99.98%	1.64
CNN-LSTM	99.53%	99.97%	0.09

Table 1 describes the performance comparison between CNN, LSTM, and CNN-LSTM. LSTM achieved the best result in precision and recall, but it costs a higher computing time (1.64ms). This is due to LSTM incorporating 3 logic gates [4] in its algorithm, hence the high computing time.

As mentioned earlier in Section II, CNN-LSTM typically used to overcome general vision-related problems. However, this study used a thermal array sensor instead of a camera which generates pixels values as output, not image. In addition, the sensor used for dataset generation is a low-resolution thermal array that has dimensions of 1x8 pixels. Consequently, noise is insignificant in the dataset. Therefore, CNN does not perform better than other compared algorithms while CNN-LSTM achieved the second-best result. In human movement, one motion leads to another motion and generates a distinctive pattern. Therefore, LSTM obtained the best result considering the dataset which contains pixel values of human movement and its ability to predict the next output from its previous data.

IV. Conclusion

This paper presented the comparison of performance evaluation between CNN, LSTM, and CNN-LSTM is presented for fall detection using a dataset generated from OMRON D6T-8L-06 thermal array sensor as the data acquisition device. The simulation result showed that LSTM has the best performance compared to other simulated algorithms (accuracy of 99.96%, precision of 99.87%, and recall of 99.98%). Due to very low computing time (lower than 1.7ms), these approaches can be implemented in environments that needed a real-time response. As for future works, the study of fall detection in higher resolution of thermal array sensor is considered, as it will likely lead to the increment of noise and affect the training phases of the model.

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