

ANN-based Stride Detection Using Smartphones for Pedestrian Dead Reckoning

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Abstract—Position awareness is a very important issue for internet of thing (IoT) applications using smartphones. Pedestrian dead reckoning (PDR) is one of the methods used to estimate a user's indoor position. The accuracy of a stride detection is very important to guarantee the estimation accuracy of the user location. This paper proposes an algorithm to detect the stride using acceleration spectrogram feature by utilizing the accelerometer in a smartphone. An artificial neural network (ANN) technology is applied to detect the stride. The proposed algorithm has an accuracy of 97.7% for stride detection.

I. INTRODUCTION

The indoor localization is an important issue for internet of thing (IoT) applications or location based services (LBS). The global positioning system (GPS) and global navigation satellite system (GLONASS) are used for positioning in outdoor environments [1]. However it is very difficult to use these systems in indoor environments because of weak signal strengths. Therefore, other methods are needed to use indoor localization. Pedestrian dead reckoning (PDR) is one of the promising technologies in indoor position estimation. PDR is a method to estimate the relative position change using the inertial measurement units (IMUs). An IMU consists of acceleration and gyroscope sensors. PDR functionalities are mainly stride detection, stride length estimation and heading estimation [2]. In order to determine the position of a user, the user's stride detection should be accurately estimated.

This paper discusses a stride detection algorithm using a spectrogram based artificial neural network (ANN) for the improvement of PDR performance. In stride detection, a 3-axes amplitude for acceleration data is considered and then its spectrogram is used to find salient features.

II. PROPOSED ALGORITHM/PROCEDURES

A. Stride Feature of Spectrogram

The main issue is determining the fitting features for stride detection in PDR. Conventional methods mainly find the peak value in the horizontal acceleration which is the impact when the foot hits the ground. Such a method [3] detects the stride using a threshold value. If the peak is larger than the threshold value, it is noted as a stride. The amplitude of the 3-axes acceleration to reflect the tilting of a smartphone is considered. However, using the acceleration value it is not possible to

estimate the stride accurately. For the higher accuracy, time is also an important factor. So, the rate of change of the acceleration is used for further processes. The spectrogram of the 3-axes amplitude in acceleration to detect the stride is then used. Fig. 1 shows a scenario of holding a smartphone firmly in hand. Acceleration data were collected while striding.



Fig. 1. Experimental environment using a smartphone.

Fig. 2(a) represents the spectrogram of the 3-axes amplitude in acceleration when holding a smartphone in hand and striding. From the figure it is noted that the strongest power is realized in low frequencies because of the gravitational acceleration. The power of gravitational acceleration is much higher than other components. It is necessary to use a filter to emphasize the striding components. For normal walking conditions, the frequencies of the stride have been assumed to range from 1 Hz to 3 Hz. A bandpass filter is used to remove noise components. It has a center frequency of 2 Hz and a bandwidth of 2 Hz. Fig. 2(b) represents the spectrogram of the 3-axes amplitude of the filtered acceleration data. The strongest power is located at 2 Hz where the gravitational acceleration and noise are removed. The spectrogram characteristic of stride is therefore realized. However, to use this spectrogram as a feature for stride detection, the spectrogram of another state must be different.

Fig. 3 represents the difference in frequency domain between stride and standing states. From the figure it is clear that the differences between the power levels of striding and standing cases. While considering in the striding case the power of the spectrum is strongest at 2 Hz. However in the case of standing it is 0 Hz approximately. So spectrogram is an important feature for stride detection. And the sequence of power ratio in frequency domain can be used for feature. So ANN architecture is implemented for stride detection.

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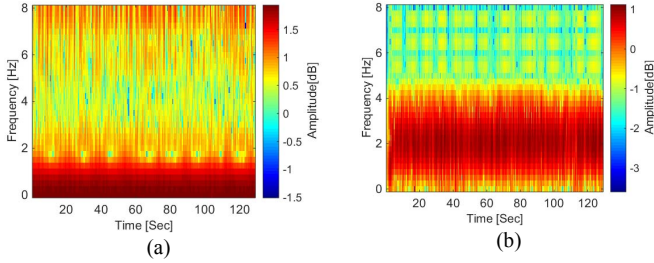


Fig. 2. Spectrograms of 3-axes amplitude in acceleration for (a) raw data and (b) filtered data.

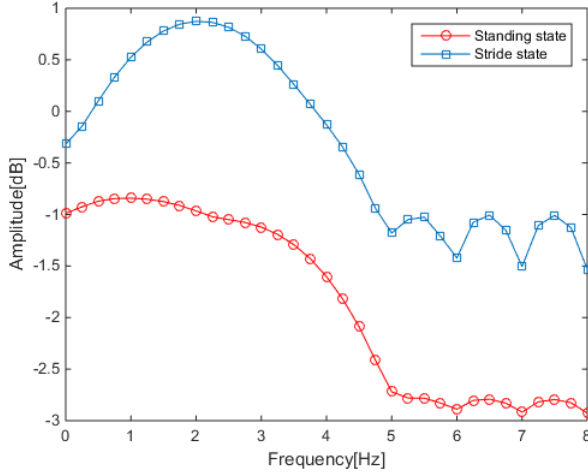


Fig. 3. Power spectral density of standing state and stride state when BPF is applied

B. Stride Detection Using ANN Architecture

For the stride detection, the ANN architecture as shown in Fig. 4 is used. The ANN architecture can be used for pattern recognition. The spectrogram feature is considered as an image, including red, green and blue (RGB) values as in Fig. 2. These RGB values are then changed to gray scales in order to reduce the input of the ANN architecture. The gray scale is obtained as

$$\text{Gray_scale} = 0.299 \times \text{Red_value} + 0.587 \times \text{Green_value} + 0.114 \times \text{Blue_value} \quad (1)$$

Finally, a data vector of 1,142 gray scale values is put into the ANN architecture at every processing instance. In the ANN architecture, the activation function and regression method are sigmoid and softmax, respectively. The back propagation method is used to update the weights in hidden layers. After many experiments the number of hidden neuron was found as 10.

III. EXPERIMENTAL RESULTS

To train the ANN, 804 vectors of data were used. Among them, 426 vectors are for the striding state and 378 vectors for the standing state. For the validation, 172 vectors were used additionally. These validation vectors were consisted of 95 for the striding state and 77 for the standing state. Finally, 172

vectors were used for evaluation of the proposed algorithm. There were 83 striding and 89 standing vectors. The results of the ANN are described in Table I. The results of stride detection are described in Table II.

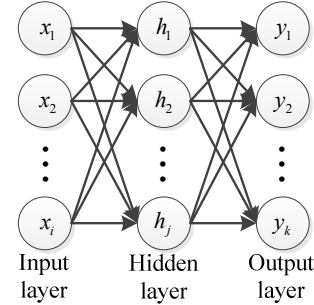


Fig. 4. ANN architecture for stride detection

TABLE I
CONFUSION MATRIX OF TRAINING DATA

	Spectrogram of striding	Spectrogram of standing state
Spectrogram of striding	412 (True Positive)	14 (False positive)
Spectrogram of standing state	7 (False negative)	371 (True negative)

TABLE II
CONFUSION MATRIX OF TEST DATA

	Spectrogram of striding	Spectrogram of standing state
Spectrogram of striding	80 (True Positive)	3 (False positive)
Spectrogram of standing state	1 (False negative)	88 (True negative)

The accuracy of stride detection is 96.3% and the accuracy of standing state detection is 98.8%. This results shows that the proposed algorithm performs well.

IV. CONCLUSION

In this paper, an algorithm for stride detection using a spectrogram based ANN was proposed. A bandpass filter to classify striding was used. Filtered data were sufficient for use as features for striding. The spectrogram was used like an image. And to reduce the input of ANN architecture, RGB values are changed to gray scales. Total accuracy of proposed algorithm was 97.7%. For future work, stride detection in other state like running and going up stairs shall be conducted especially because each of the motion artifacts produce different spectrograms.

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