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Research paper

Human Detection and Classification using Passive forward Scattering Radar

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Abstract

Passive forward scattering radar is a system that can detect any present object that is passing through between the transmitter and receiver. The technique used for detection of human is called forward scattering technique. It is used to detect human who passes within the range of forward scatter region. Moreover, passive radar system doesn't have its own transmitter but it can receive the power signal from any commercial transmitters. For this research work, commercial transmitters that transmit frequency of Long-Term Evolution (LTE) which is 1.8 GHz were used. When a human passes through between the transmitter and receiver, a wave called the Doppler signal is produced in the forward scatter region, and it is then captured by the passive radar receiver. For data acquisition, 3 individuals of different height were involved, which is Person 1 (1.57m), Person 2 (1.56m) and Person 3 (1.47m), and the location of the experimental work was constructed in the real environment at the seaside of Morib, Malaysia. The reason the seaside was chosen was based on past cases of intruders crossing the border of Malaysia through the seaside at Lahad Datu, Sabah. All of the data was collected and analyzed using Matlab software. From the experiment results, it was shown that the passive forward scattering radar system successfully detected and classified the human presence while walking and running, where running was more easily classified because of the increasing speed compared to walking.

Keywords: *LTE, forward scatter, passive radar, human detection, classification*

1. Introduction

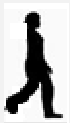
Radio Detection and Ringing (Radar) is a system commonly used in detection of objects passing through the region between a transmitter and a receiver. Some examples of detection are distance, angle, speed of vehicles and other objects. Radar is widely used in many applications for example surveillance, tracking and also military needs. There are 2 types of radar system, which are active radar and passive radar. The active radar is more complex compared to the passive radar because the active radar has its own transmitter while the passive radar does not. In this paper, the forward scattering radar was used to detect Doppler signatures produced by humans of different height and size while walking and running. To compare the Doppler spectrum of different postures, sizes and gender, differences of amplitude and bandwidth were observed [1].The Passive Forward Scattering Radar (FSR) is used to detect humans passing through between the transmitter and receiver with an angle near to 180 degrees [2]. It needs to be in the line of sight in order to get a strong signal from the transmitter, and with the strong signal strength, the detection of human will be good. The advantage of FSR is the ability to detect the movement of target through perturbations in direct path which is the line of sight. Moreover, the FSR is suitable for human detection especially on the ground and is also suitable for border protection security [3].
Data was collected and analyzed by using the Matlab software. The first step of data processing was cropping the raw data to 4 seconds from its original 20 seconds. The raw data of 4 seconds then underwent a denoising process, which is in time-domain using wden function in Matlab software which performs an automatic denoising process of a one dimensional signal using wavelets. Time-domain methods are used to survey time detection performance [4]. Then the data were processed using pwelch function, which is a method of Welch's in the Matlab software. This method is used to estimate the power spectral density (PSD) of a signal. During the Welch process, the value of Fast Fourier Transform (FFT) is considered and used to test for any presence of each frequency of target and to produce the three dimensional image [5]. Then the denoised data and PSD are used in order to convert the data into Principle Component Analysis (PCA). The PCA uses an orthogonal transformation and it is used to differentiate and identify the pattern of data.
The main objective of this study is to prove that the Doppler signatures produced by humans are different because of differences in body height while walking and running. This paper used 3 different individuals. Besides that, the objective is to analyze and differentiate 3 individuals using their Doppler signatures in the Matlab software.

2. Methodology

2.1. Person

This study used 3 individuals as the target of detection. Each individual has different height and body size and their description is shown in Table 1. Although the description of the 3 individuals have different height and body size, it is worth noting that the height of Person 1 and Person 2 are almost the same. Person 3 was much more different in size compared to Person 1 and Person 2. The height of individual will influence results of detection.

Table 1: Information of individuals

Type of Person	**Height (m)**	**Silhouette**
Person 1	1.57	
Person 2	1.56	
Person 3	1.47	

2.2. Site of Experiment

The location of the experimental work was constructed in the real environment by the seaside of Morib. The seaside area was chosen based on past cases of intrusion, whereby some intruders crossed the Malaysian border through the seaside at Lahad Datu, Sabah. Besides, the LTE power signal was strongly received from the nearest tower of transmitter. Fig. 1 shows the experiment site at Morib. The distance between the commercial transmitter that was the base station and the passive radar system was 372 m.

Fig. 1: Experiment site at Morib

The signal strength transmitted from the transmitter is shown in Fig. 2, where the strength of the signal transmitted from the commercial transmitter located near the experimental site had a frequency of 1.8 GHz and was provided by Maxis Berhad. The provider was confirmed by referring to the Malaysia wireless frequency band. 30 dB was the strength of signal transmitted and it was suitable for human detection. The stronger the signal, the better the detection.

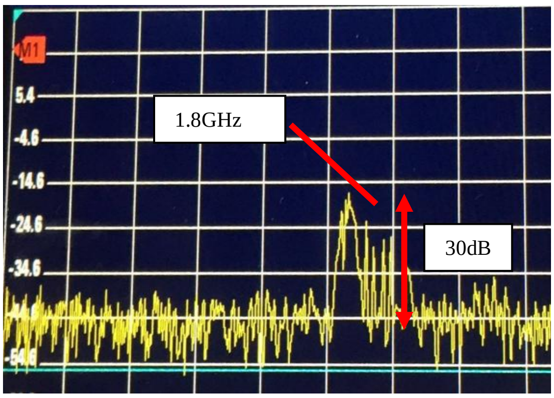


Fig. 2: The strength of signal from transmitter

Refer to Table 2, the individuals passed through the passive radar system with a distance between target and receiver of 1 meter. Each individual passed through the receiver with different actions, which were walking and running. The total of samples for both behavior is 229.

Table 2. Number of Expriment sample

Type of Person	**Walking (Number of samples)**		**Running (Number of samples)**	
	Training	**Testing**	**Training**	**Testing**
Person 1	26	5	34	5
Person 2	40	5	31	5
Person 3	37	5	31	5
TOTAL	118		111	

The arrangement at the experiment is illustrated as in Fig. 2, where each individual had to pass through between the receiver and transmitter.

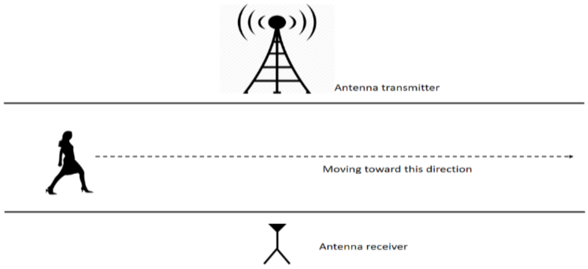


Fig. 2: The illustration of experiment site

2.3. Data Processing

Based on the experiment that was done in Morib, after all of the data was collected, the next step was data processing. Data was processed and analyzed using the Matlab software. This project used Matlab software because it was suitable in the plotting of function and data. There were many data plotted using this software, namely denoised, pwelch and PCA.

The flow chart in Fig. 3 shows the flow of data processing. The first step was data selection, where the good signal was selected. Data with too much noise was avoided during selection. Then we continued with processing data segment. During data segment, data was cropped into 4 seconds data in time domain.

The next process was signal denoising, where the process involved removing some noise from the signals. During signal denoising, the signal was clearer compared to the 4 seconds data because the unwanted signal had been removed. Beside that the signal was also adjusted to the correct position in order to make it easier for the next process and also for analysis.

After all the noise was reduced from the signal, the next step was to develop the power spectral density, where the data is in frequency domain. The denoised and power spectral density data were both used in order to convert into PCA. During PCA, a large number of related variables were reduced. Besides that, the PCA will remain as much as possible of the variation in the data set for classification of data.

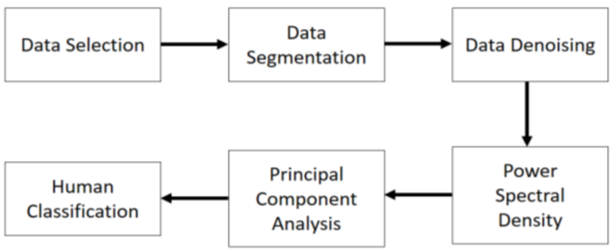


Fig. 3: Flow chart for data processing

3. Result

3.1. Time Domain

In an FSR system, the Doppler signature has a high resolution when the target is located within the FSR signal beam width. Furthermore, the range between the target and receiver also influence each other, where the signal is clearer when the target is closed to the receiver. In this case, the distance between the target and receiver was 1 m and each individual had to walk and run within the FSR region.

Fig. 4 shows the raw data of time-domain for 3 person walking. The time range of Doppler signal for running was shorter than walking. This is because of speed. For walking, the time range of Doppler signal was 1.7 seconds. Additionally, the pattern of the Doppler signal for walking and running also had differences.

Fig.5 below shows the raw data of time-domain for 3 individuals running. The differences of Doppler signature between the 3 person were differentiated by Person 3 (black line), where there was a small amplitude at 2 seconds compared to others. In the meantime, Person 1 and Person 2 were difficult to differentiate because the height of Person 1 and Person 2 were similar. Moreover, the range time of Doppler signal for running was 0.7 second.

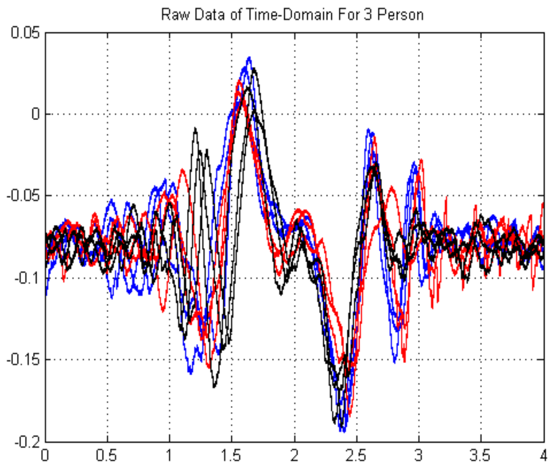


Fig. 4: Raw data of Time-Domain for 3 person (walking)

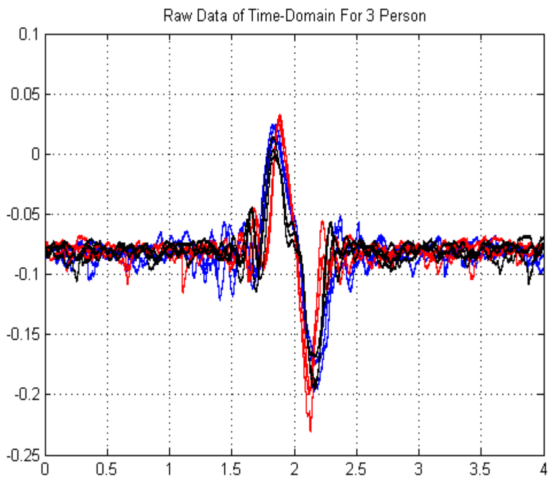


Fig. 5: The raw data of Time-Domain for 3 Person (running)

Fig.6 and Fig.7 show the raw data that have been through the process of denoising, which used the wden function in MATLAB software. Data that were removed of noise are clearer compared to raw data.

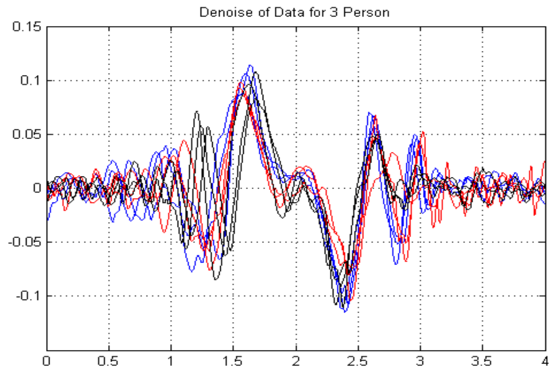


Fig. 6: Denoised data for walking

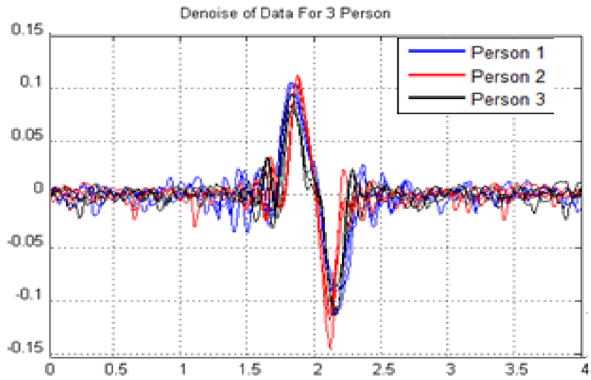


Fig. 7: Denoised data for running

3.2. Power Spectral Density of Vehicle Detection

Power spectral density is the data that within the frequency domain and normalization power in dB. The different heights of each person will affect the scattering signal. Fig. 8 shows the PSD for walking, where the difference was clear in Person 3 (1.47m) who had a small PSD compared to Person 1 (1.57m) and Person 2 (1.56m). Fig. 9 shows the PSD for running and it shows that Person 1 (1.57m) and Person 3 (1.47m), in terms of PSD, were easily differentiated because of the difference of heights. Besides that, the difference in Person 1 could also be seen when the PSD of Person 1 was larger than PSD of Person 2 and Person 3. From both results of PSD, the bandwidth are different because of the height of each person.

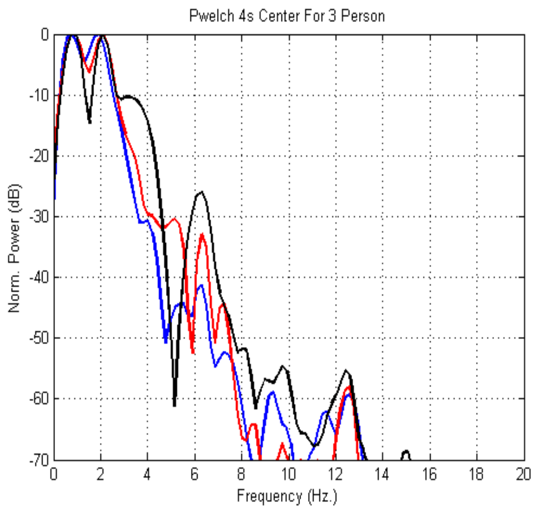


Fig. 8: PSD for walking

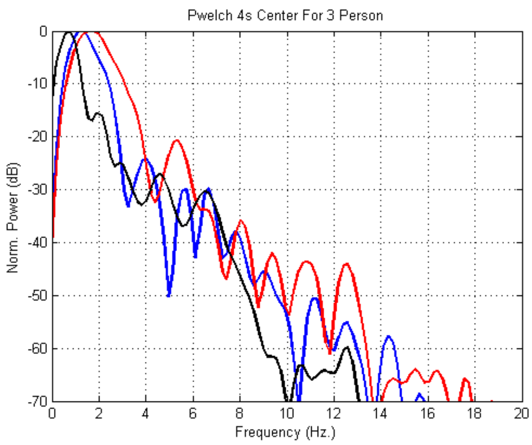


Fig. 9: PSD for running

3.3. Principle Component Analysis

For principle component analysis (PCA), the results show 3 types of points that represent individuals for walking. Fig. 10 shows that the group of Person 1 (blue diamond) and Person 2 (red dot) overlap each other at the left of the PCA graph. But for Person 3 (black triangle), the points gather at the right side of the PCA graph. Referring to Fig. 11, the group of points that represent Person 2 (red dot) is located on the right side of the PCA graph. Also, there are combination of groups between Person 3 (black triangle) and Person 1 (blue diamond) that overlap each other. Moreover, when the speed decreased, the classification were almost mixed together and it can be seen in Fig. 12.

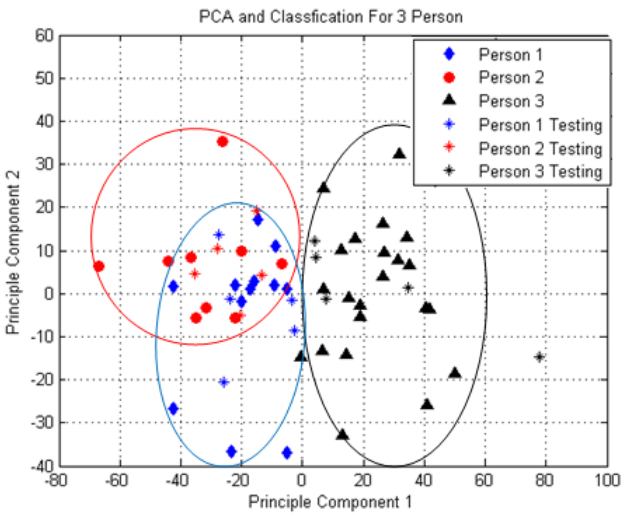


Fig. 10: PCA and classification for walking

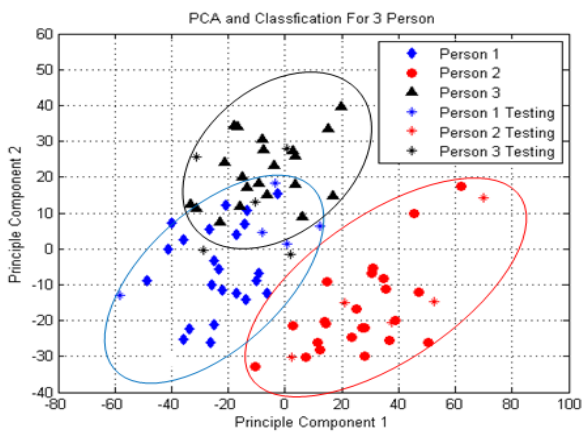


Fig. 11: PCA and classification for running

3.4. PCA Variance

For results of PCA variance, Fig.12 shows the value of variance explained for bar 1, which represents the principal component 1 that was around 40% and the total variance was 99% divided by 8 principal components used for walking. Fig. 13 below shows the value of variance explained for bar 1, which was near 60% and the total variance was 99% divided by 5 principal components for running. These results show that the PCA variance for running is higher than walking.

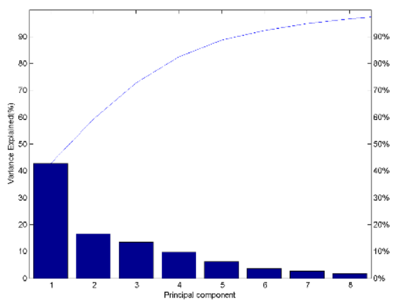


Fig. 12: The PCA variance for walking

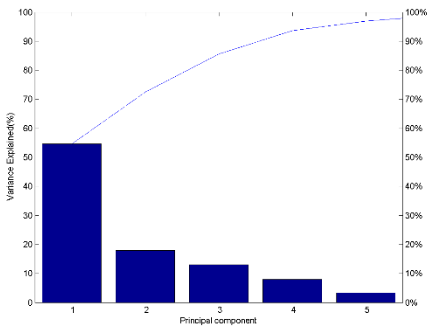


Fig. 13: The PCA variance for running

3.3. Confusion Matrix

Refer to Table 3, for classification of Person 1, there is an overlap between Person 1 and Person 2 with 16.13% and 83.87% represents Person 1 in the correct position. Person 3 had 0% because there was no overlap with the other groups. Meanwhile, classification of Person 2 there is an overlap between Person 2 and Person 1as much as 4.45% and 95.55% represents the Person 2 in correct position. Person 3 had 0% because there was no overlap with the other groups. Person 3 was 100% classified.

Refer Table 4, for classification of Person 1, there is an overlap between Person 1 and Person 3 as much as 5.13% and 94.87% represents Person 1 in the correct position. Person 2 was 100% classified because there was no overlap with other the groups. Meanwhile, for classification of Person 3, there is an overlap between Person 3 and Person 1 at 5.55% and 94.45% is represents the Person 3 in correct position.

Table 3: Confusion matrix for walking

Person	Number of samples	Automatically classified (%)		
		Person 1	Person 2	Person 3
1	31	83.87	4.45	0
2	45	16.13	95.55	0
3	42	0	0	100

Table 4: Confusion matrix for walking

Person	Number of samples	Automatically classified (%)		
		Person 1	Person 2	Person 3
1	39	94.87	0	5.55
2	36	0	100	0
3	36	5.13	0	94.45

4. Conclusion

As a conclusion, the passive radar has the ability for detection especially the detection of humans. For this study, the results of data processing the Doppler signal produced by humans are unique and was depended on the body size. Beside the classification, the 3 individuals can also be differentiated based on the PCA results. The speed of movement provides a good clusterization in principle component analysis (PCA). Furthermore, the passive radar has its own advantages such as the system cannot be jammed by anyone because it does not transmit any power signal and it is suitable for military and protection security system.

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