Baseline Classification Based PCA on Human in Passive Forward Scattering Radar

N.H. Abdul Aziz[1,2], N.N. Nasir[1] and M.T. Ali[1]
[1]*Antenna Research Group, Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM), Shah Alam, 40450, Selangor, Malaysia.*
[2]*Faculty of Engineering, Universiti Putra Malaysia (UPM), Serdang 43400, Selangor, Malaysia.*
noor4083@salam.uitm.edu.my

***Abstract*—First and foremost, one purpose of this radar is for detecting objects that passes through the system, whereby the detecting angle is near 180 degrees. Passive radar detects presence in terms of direction and speed of aircrafts, ships and other objects at receiver baseline, by receiving illumination source from a commercial transmitter. The system of radar consists of a receiver that functions to determine the properties of the passing object. There are many techniques that can be used in passive radar but in this study, the forward scattering technique is used for detecting human Doppler signature at receiver baseline to the classification system. A commercially available telecommunication antenna is used as the transmitter, which transmits electromagnetic wave that is received by a receiver antenna. We called this system passive radar because it does not emit any waves of its own. The data of Doppler signature is produced when an object passes through the transmitter and receiver. Then, the data received by the receiver is collected and analyzed using MATLAB software. The data collection was implemented near the seaside at Morib beach, Malaysia. We have identified the site as having a strong signal of LTE with a signal frequency of 1.8 GHz and 2.6 GHz.**

***Index Terms*—Forward Scatter Radar; Human; Passive; Principal Component Analysis.**

I. INTRODUCTION

There are many techniques in passive radar that can be used for detecting a target. One of the techniques is by using a third-party transmitter like Frequency Modulation (FM). FM is used to determine the target range and it's developed by an algorithm based on cross correlation. An algorithm is created so that it can be used in very low Signal Noise Ratio (SNR) [1]. Besides FM, Ultra-Wideband (UWB) is also one of the technologies used in radar. UWB is used to differentiate between animal and human. The vital sign classification is detected by the UWB radar. The difference on correlation coefficient of body micro vibration is detected to differentiate between human and animal [2]. Quasi Multiple Input-Multiple Output (MIMO) technique can also be used in radar, which is for indoor human detection. In the indoor measurement, the detection will usually be reflected by the wall, furniture and other objects inside the area. So, extract radar echoes is used to remove unwanted responses based on the Khatri-Rao matrix product [3].

Another use of radar is in border protection. Forward scatter radar is an efficient way to accomplish that. FSR operates in a narrow scattering area along the system baseline, which is between commercial transmitter and receiver antenna. Forward scatter cross section is more efficient in comparing the magnitude of the targets. Theoretically, the Doppler signature is very strong inside the forward scatter area [4].

In order to detect near field region of FSR, the characteristics of the received signal are analyzed. The target is detected when it crosses the baseline to the classification, and the data is analyzed based on a suitable numerical evaluation. Based on the analysis, the amplitude of the target detected by FSR is different, depending on its size and its distance from the receiver antenna [5].

II. METHODOLOGY

A. Human Target

Three persons were used as the ground moving target for this project. Each person was different in height, and the distance ranged from 1 meter to 3 meters. The description on the human targets used are as in Table 1.

Table 1
Information of human target

Category	Height (m)	Silhouette
Person 1 (medium)	1.56	
Person 2 (big)	1.57	
Person 3 (small)	1.47	

B. Experiment Site

The location chosen to conduct this experiment was by the seaside of Morib, Malaysia as shown in Figure 1. This is because the area has a strong signal of mobile network from a nearby transmitter base station.

The passive radar system was used to receive the signal power strength from the commercial transmitter located 330 meters away from the radar receiver baseline.

In Table 2, the receiver, acting as the passive radar, detected human presence that passed through the area between receiver antenna and commercial transmitter. Each person, the moving target, were to pass through three distances, which are 1 meter, 2 meters and 3 meters. The total data taken for 1 meter, 2 meters and 3 meters is 41, 59 and 51 data respectively. The arrangement at the experiment site is illustrated in Figure 2.

Figure 1: Experiment site at Morib, Malaysia

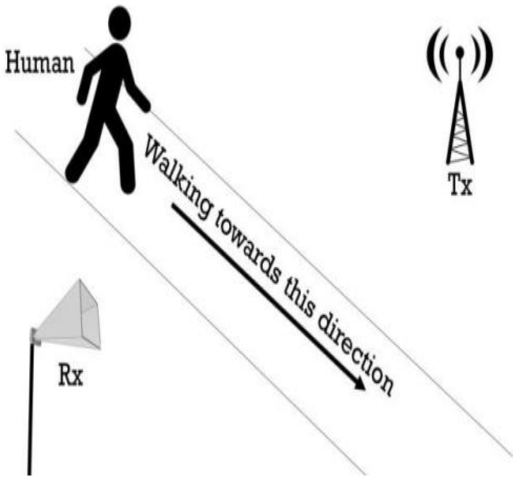


Figure 2: Illustration of target moving at the experiment site

Table 2
Number of Sample Experiment

Person	Number of sample for 1 meter		Number of sample for 2 meters		Number of sample for 3 meters	
	Training	Testing	Training	Testing	Training	Testing
1	8	5	15	5	16	5
2	9	5	17	5	15	5
3	9	5	12	5	5	5
Total	26	15	44	15	36	15

C. Data Processing

In this study, MATLAB software was used for all collected data. MATLAB software is commonly used by engineers to optimize problem solving. It can express in mathematics based on matrix language. For built-in graphics, it can visualize and gain insight of the data. The multi-paradigm numerical computing environment allows developers to interface with programs developed in different languages, which makes it possible to harness the unique strengths of each language for various purposes. From the data collection, the best of data are selected. The time domains are created based on data selection. The data collected is a result for several range of distances, which are 1 meter up to 3 meters for each of the human moving target. Obviously, humans do not have the same body build. At the experimental site, the data was recorded for 20 seconds. Next, the data is processed with only 4 seconds that contains the human Doppler signature.

III. RESULT AND DISCUSSION

A. Time Domain

The received amplitude signal is in time domain, used in the Forward Scattering Radar (FSR) technique. As shown in Figure 3, the horizontal axis represents time that is proportional to the human Doppler Signature. As a result, each distance have differences of amplitude, and every amplitude is different for different person. The distance between the receiver antenna and human ranged from 1 meter to 3 meters. The blue line represents 1 meter, and it indicates the highest amplitude compared to the others. The red line is 2 meters and the black line is 3 meters. It shows the distance of human from the receiver antenna, which influenced the amplitude height, wherein the higher it is, the closer the human is to the receiver antenna, and the higher the signal formed.

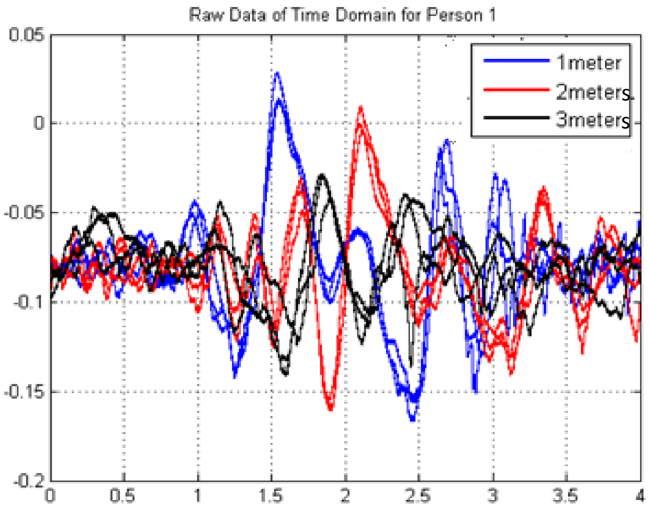
As we can see, the human Doppler signature can clearly be seen at both ends of the signals when the human was entering and leaving the baseline, and the horn antenna acted as the receiver that started to receive the target's forward scatter lobe. For Figure 3, the time taken for the Doppler signature to be detected was from 1 second to 3 seconds, with a mean time recorded of 2 seconds. As we can see, each person produced different Doppler signature. This demonstrates that the time for Doppler signature to be produced depends on the human body build and the range of distance. When the range increased, the amplitude of Doppler signature decreased.

B. Power Spectral Density

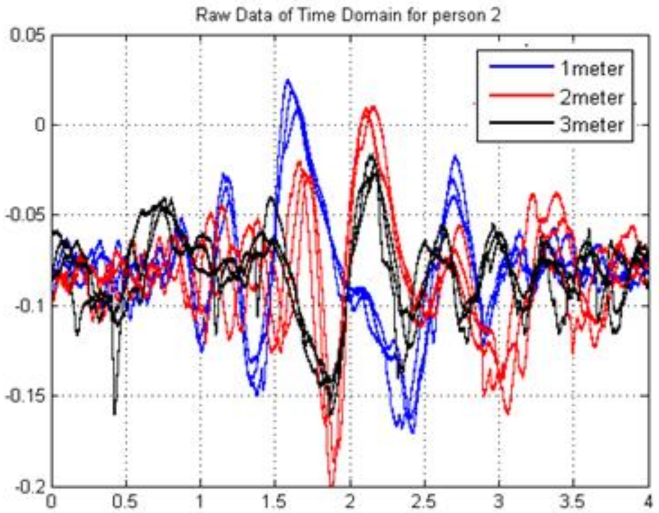
The signal's power spectral densities of the same range for different human are showed in Figure 4. they are compared in frequency and normalized power (dB). This relationship is used to estimate the human range from the receiver antenna. As can be seen from the figure, the small range, which is 1 meter, recorded the highest normalized power followed by 2 meters and 3 meters. This indicates that the closer the distance range, the higher the power produced.

C. Principal Component Analysis

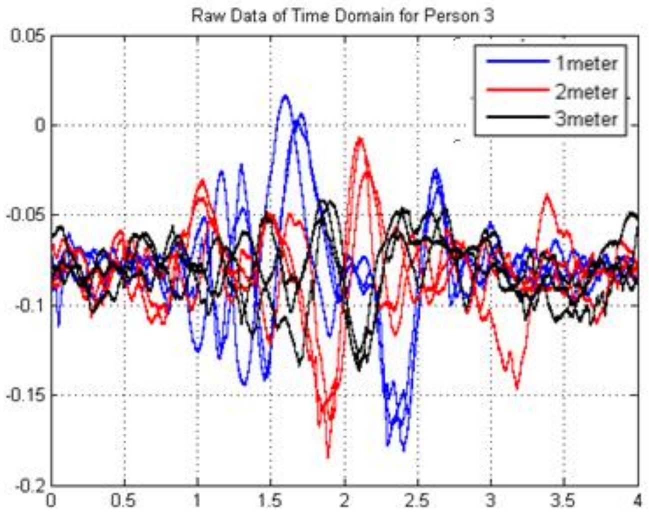
The result of principle component analysis (PCA) is showed in Figure 5. The point is produced for difference of range and difference of human. The farthest distance is represented by black triangles, which is for 3 meters. The mid-range distance of 2 meters is indicated by red dots, and blue diamonds represent 1 meter of distance. Most of three person at the range of 3 meters do not mix with other ranges, and the graph are spread fairly wide apart within their own cluster. Most 1 meter and 2 meters ranges overlap each other, and the plotted graph are much closer to each other in distance within their respective clusters.



(a)

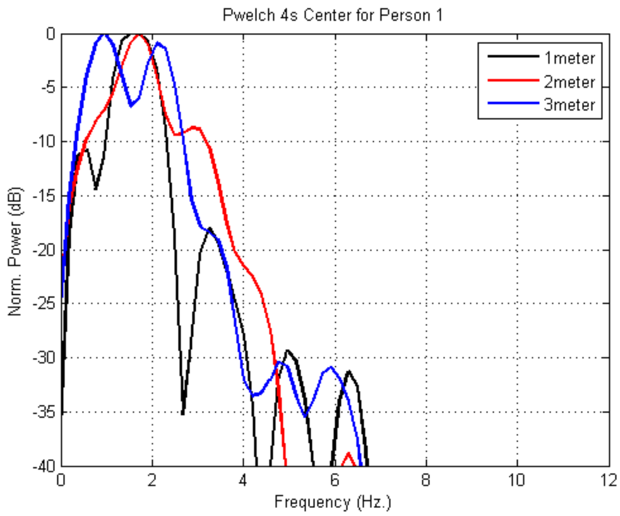


(b)

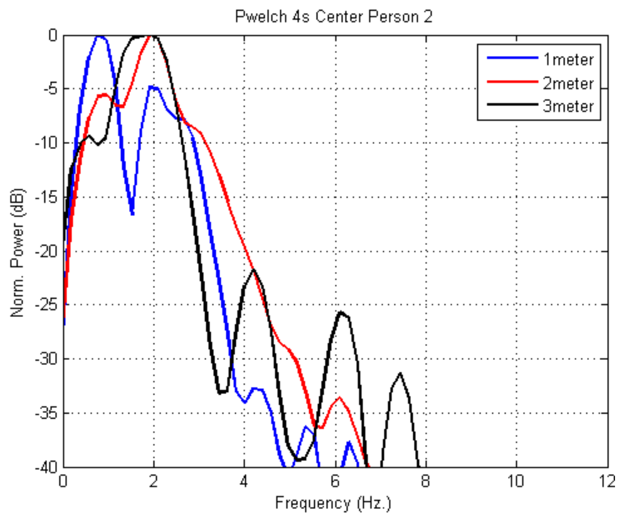


(c)

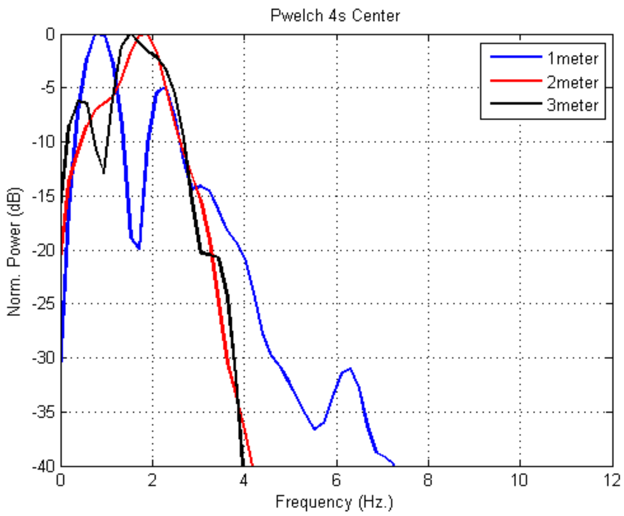
Figure 3: Time domain of (a) Person 1, (b) Person 2 and (c) Person 3.



(a)



(b)



(c)

Figure 4: Power spectral density of (a) Person 1, (b) Person 2 and (c) Person 3.

In Figure 5(a) the distance between the points become closer in their own cluster. The lower range shown by blue diamonds on the left, while 2 meters indicated by red dots are in the middle, and on the right are black triangles representing 3 meters. As shown, the result indicated all 3 ranges do not mix with each other for person 1. In Figure 5(b) the distance between the points became closer in their own cluster especially at range 1 meter and 2 meters. The lower range are blue diamonds on the left side, while 2 meters indicated by red dots are in middle, and both ranges overlap by half of their cluster. On the right are black triangles, which is for the range 3 meters. As shown, the result indicated the range of 3 meters does not mix with other clusters for person 2. Lastly, in Figure 5(c) for person 3, the result is most similar to that of person 2. This is because the body build for person 2 and 3 is similar.

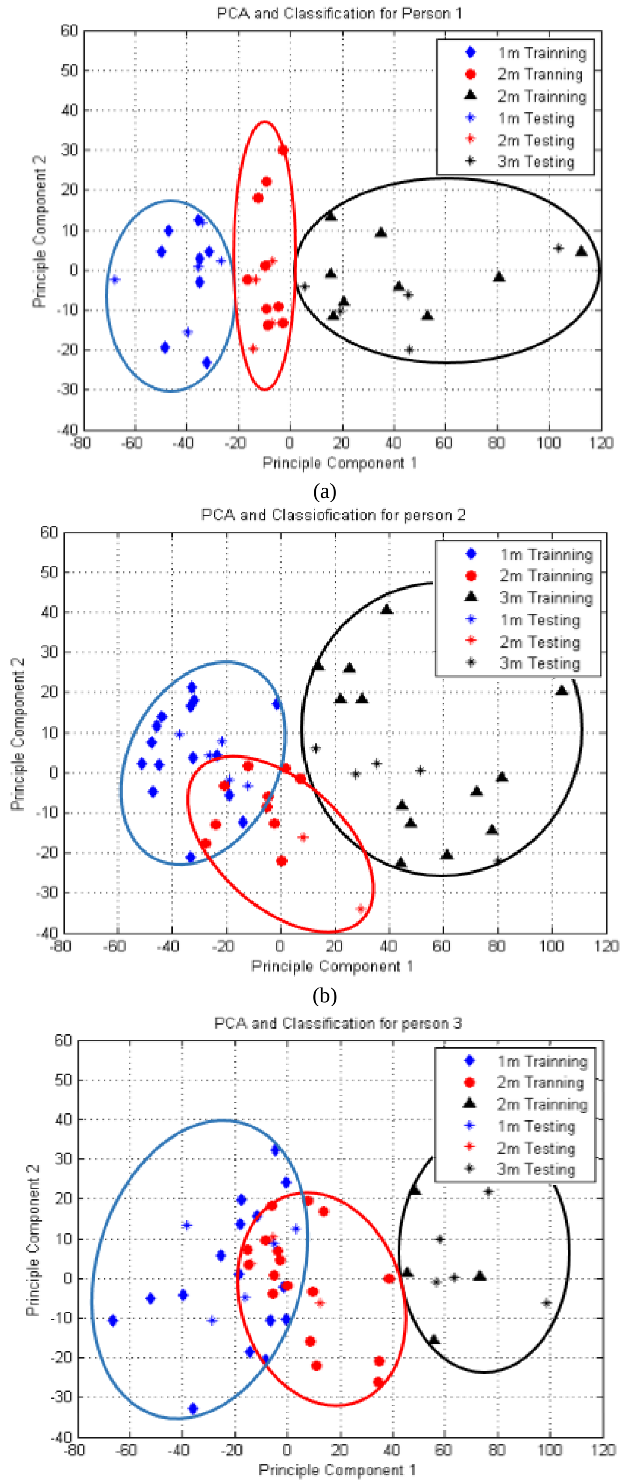


Figure 5: Principal component analysis of (a) Person 1, (b) Person 2 and (c) Person 3.

IV. Conclusion

In this study, forward scattering technique is used to detect human as a moving target. The detecting angle is near 180 degrees for this research work focused on baseline classification system. Passive radar does not emit any waves of its own and so, it only builds a receiver antenna baseline to the classification and receives the signal wave power from an existing commercial antenna. By setting up 3 sets of human targets in 3 different ranges, specifically varied from 1 meter, 2 meters and 3 meters for each human respectively, the Doppler signatures were collected and processed in MATLAB software. The data were analyzed and the result discovered where the difference of range does not have the same Doppler signature for each person. This is proved by the result as shown in this study

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