

# Application of Ultra Wide Band Radar for Multiple Human Tracking with CLEAN Algorithm

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## Abstract

We track multiple human subjects using ultra-wide band (UWB) radar based on their target signatures. To resolve the correspondence problem, the use of CLEAN algorithm is proposed. Walking two human subjects are measured by UWB radar. The feasibility of classification is investigated using the suggested method.

**Keywords :** UWB radar, Human tracking, Target classification

## 1. Introduction

Multiple human tracking is a topic of recent interest due to the increased demand for security and surveillance. To monitor human subjects, diverse technologies have been developed, including computer vision, infrared detectors, Ladar and radar. Among them, radar offers a unique advantage compared to the other technologies because it has the ability to penetrate through obstacles and detect targets in all weather conditions [1]. The use of ultra-wide band (UWB) radar is an emerging technique that has high resolution for target detection. Thus, UWB radar has been applied for human detection problems. A human subject was distinguished from animals and vehicles using the CLEAN algorithm [2, 3]. By investigating the change of the returned pulse shape, human activities were also classified [4, 5]. Multiple target tracking with target signatures, however, has not been extensively researched.

In this paper, we proposed to track two human subjects using UWB radar. We solve the correspondence problem based on the time-varying target signature. The correspondence problem occurs when target echoes overlap in the range profile when they are located at the same physical distance. Each human has its own walking style such that the human walking signature is used to distinguish the subjects. We employ the CLEAN algorithm to characterize an UWB echo that is related to human posture at an instant. Because human walking style is a series of postures, we consider the time-varying signature of returns. Through investigating the signature of outputs of the CLEAN algorithm, two returns are classified and targets are tracked. Two walking humans are measured using UWB radar. Measurement, signal processing, analysis and results are reported.

## 2. Measurement and Pre-Processing

Measurements are performed using the P220 UWB radar manufactured by Time Domain Co. Ltd. The employed UWB radar system consists of two P220s, two horn antennas, a router and a computer to record the data. The radar operates in the bi-static mode. We use high-gain horn antennas for the purpose of increasing signal power illuminating the target. For the measurements, two human subjects walk in from of the radar with their own walking style. The whole setup is placed in an open space so that there is no other scatterer in the neighbourhood that causes interference. Still small amount of reflection can happen from the ground. To make the walking style distinct, one human subject either walks with a large arm swing or carries a cylindrical reflector while the other subject walks normally as shown in Figure 1. We tested two paths as depicted in Figure 2. In the first path, one human subject moves forward and the other moves backward with respect to the radar. At certain time, the echoes from each person cross each other in the range profile. In the second path, the echoes meet and overlap, but do not cross each other because one subject is always close to the radar and the other is far from it. We measure four cases composed of two different walking paths with two different walking styles.



Figure 1: Different walking styles (a) Walking with large arm swing, (b) Walking with a cylindrical reflector

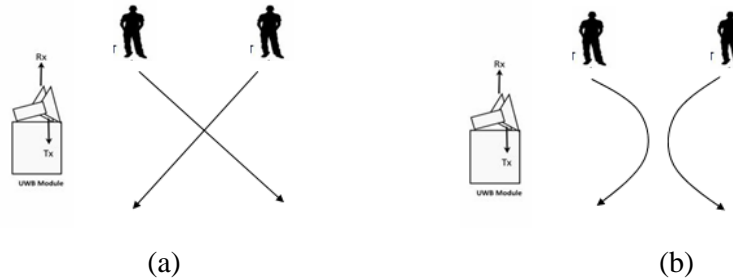


Figure 2: Two different walking path

The data recorded during the measurements need to be pre-processed for tracking. The pre-processing includes elimination of the direct coupling and amplitude normalization of the data. The processing is performed by MATLAB. Figure 3 shows a sample range profile of a single scan. The figure shows direct coupling between the Tx and the Rx and two echoes from the two human subjects. To remove the direct coupling and reflected signals from ground clutters, we subtract the ambient signal from the measured signal. The ambient signal is captured without human subjects to receive ground clutters and noises. Because the pulse shape depends on the posture of the human, echoes are extracted and normalized to remove the distance effect and reduce the complexity of the data. The normalized signal is analyzed by the CLEAN algorithm.

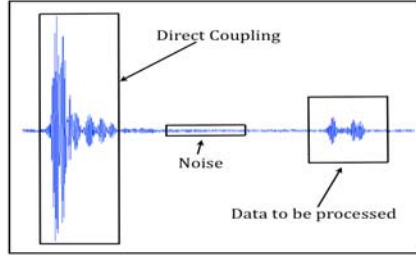


Figure 3: Range profile of a single scan

### 3. Analysis by the CLEAN Algorithm

When a human subject is illuminated by an UWB signal, the received signal can provide distinguishable information about the target. A return from a human subject is complex because different body parts reflect the incident wave at different times with various amplitudes. Therefore, the returned echo at an instant is superposition of multiple returns from the different parts of the human body. We employ the CLEAN algorithm to decompose the received echo into several template signals. The CLEAN algorithm was developed to detect a weak target in the presence of a strong target in astronomy. The algorithm iteratively subtracts the response of the strongest target from the total response one after another. It has been applied to the analysis of human scatters recently [2, 3]. The CLEAN algorithm estimates the time-delay and amplitude of each scatterer of the human body with the provided template waveform. Humans could be successfully classified among animals and vehicles through investigating the output of CLEAN algorithm. In our study, we decompose the human echoes into five template signals with different amplitudes and time delays. An echo from a cylindrical reflector is used as a template signal. Through the operation of cross-correlation, the coefficients of the CLEAN algorithm are computed. Finally, we extract five time-delays and five amplitudes, resulting in ten coefficients. The iterations can be extended further to decompose more scatterers, but we limit the number of iterations because it is sufficient to capture the signature of the returns. The concept is depicted in Figure 4.

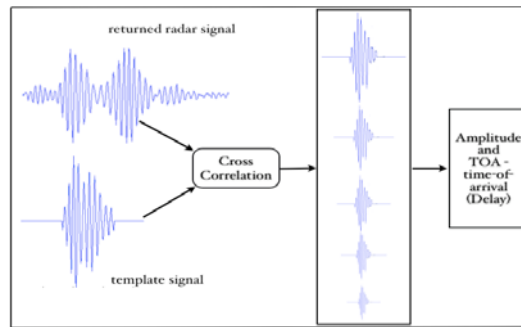


Figure 4: Concept of application of CLEAN algorithm to UWB signal

The estimated ten coefficients of the CLEAN algorithm correspond to a certain human posture at an instant. However, the walking style is not determined by the coefficient itself, but how the coefficients vary with time. Under the assumption that each human has its own unique walking style, the time-varying characteristic of the CLEAN coefficients is utilized to capture the characteristic of a walking style. Within the time window, the normalized echoes are analyzed by the CLEAN algorithm. In this study, we set the time window to 1.5 sec. It is enough time to capture at least one period of human motion. We investigate the variation of CLEAN coefficients within the time window to see the difference. The maximum and minimum values are compared. Finally two

human subjects could be successfully distinguished for two scenarios measured. The result is shown in Figure 5.

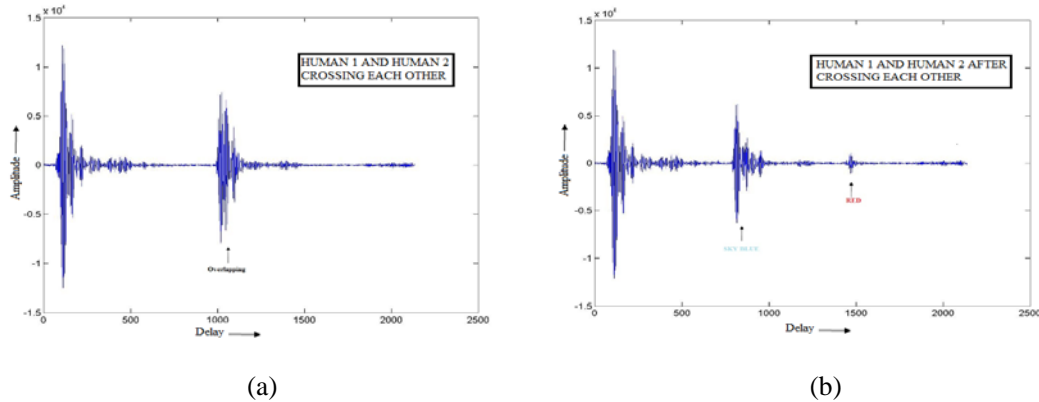


Figure 5: Tracking result. (a) When two echoes overlap, (b) Classification result after overlapping

## 4. Conclusion

We investigated the feasibility of solving the correspondence problem in tracking multiple humans using UWB radar. We used the CLEAN algorithm for extraction of human walking signatures. The signal obtained from the human subject is pre-processed to remove the direct coupling and the background noise. The CLEAN algorithm decomposes returns into several template signals to express the complex return with a few coefficients. The time-varying characteristic of the coefficients is used for the classification of two walking humans. The suggested algorithm could successfully classify the two humans and track them.

However, there are several issues to be investigated further. In this paper, we used a data set measured in the controlled environments. Two humans had quite different walking signatures. In reality, people walking style can be similar to each other. In that case, it can cause low classification accuracy. Also this research limits the number of targets to two people. When the number of target is large, the correspondence problem becomes quite complex. In our study, the walking trajectory was smooth. However, the characteristic of UWB echo should be investigated when the walking direction of a human subject changes abruptly.

## References

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