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

### (Education of Radar System through Graduate Project)

**Youngwook Kim and Jagjit Singh**
**Electrical and Computer Engineering**
**California State University at Fresno, USA**
**Email: youngkim@csufresno.edu**

## 1. Introduction

Radar systems consist of RF hardware and a signal processing unit. The RF hardware generates high frequency signals, transmits and receives it to detect echoes from a target. The signal processing unit processes data received from the hardware to recognize the target and extract information about it. Therefore, a project using a radar system can provide an opportunity for students to acquire knowledge and hand-on experiences on hardware as well as software.

Multiple human tracking is an interesting topic due to the increased demand for security and surveillance. To track human subjects, diverse technologies have been developed, including computer vision, infrared detectors, Ladar and radars. 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 immerging technique that has high resolution for target detection. The use of UWB radar for human detection has been researched. A human subject was distinguished from animals and vehicles through use of the CLEAN algorithm [2, 3]. Through the investigation of the change of the returned pulse shape, human activities were also classified [4]. Multiple target tracking with target signatures, however, has not been extensively researched. Therefore, it can be a proper graduate project for the purpose of education as well as research.

In this project, we proposed a method to track multiple human subjects using UWB radar based on the time varying target signature. We solve the correspondence problem that occurs when target echoes overlap. The human walking signature is used to discriminate the subjects. Each human has its own walking style such that the target can be recognized by the talking (walking?) style. We employ the CLEAN algorithm to characterize human posture at an instant. Because human motion should be examined by a series of postures, we consider the time-varying signature of the coefficients. Two walking humans are measured using UWB radar; they are classified and tracked by the suggested method. Measurement, signal processing and analysis are performed by graduate students.

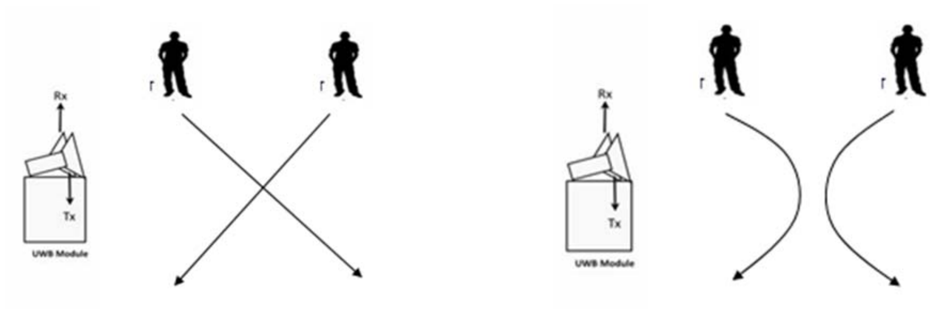
Four main learning objectives are pursued in this project. They are: (i) students understand the basic concept of UWB radar system, (ii) students operate the UWB radar to measure human movements, (iii) students understand diverse signal processing algorithms, (iv)students implement each signal processing block using MATLAB.

## 2. Measurement and Pre-Processing

Two walking human subjects are measured by P220 UWB radar manufactured by Time Domain Co. Ltd. The graduate students are trained to operate the UWB radar system, which consists of two P220s, two horn antennas, a router and a computer to record the data for the bi-static operation. We use high-gain horn antennas for the purpose of increasing signal power illuminating the target. Figure 1 represents one example of the measurement setup.

Figure 1: Human subjects with UWB radar

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 reflecting object in the neighborhood that causes interference except the reflection of the signal from the ground. In order to make the walking style distinct, one human subject walks with a large arm swing or carries a cylindrical reflector. We tested two scenarios as shown in Figure 2.




(a) (b)

Figure 2: Two measurement scenarios

In the first case, the echoes from each person cross each other in the range profile because one human subject moves forward and the other moves backward with respect to the radar. On the other hand, the echoes do not cross each other in the second scenario. The data recorded during the measurements need to be pre-processed for tracking. The graduate student performed pre-processing including elimination of the direct and normalization of data using MATLAB. Figure 3 shows a sample range profile in a single scan.

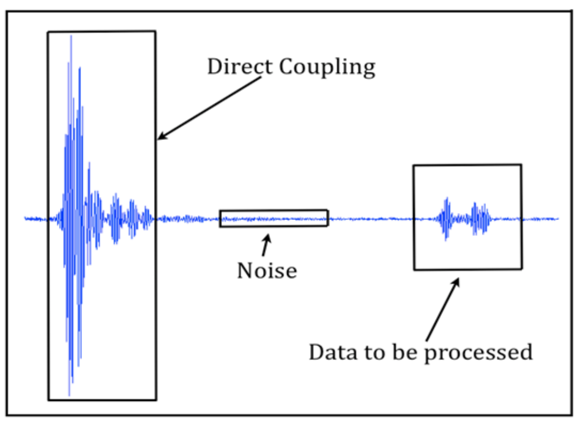



Figure 3: Range profile of single scan

The figure shows that there is direct coupling between the Tx and the Rx antennas 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 measured without human subjects to capture ground clutters and noises. Then echoes are extracted and normalized to remove the distance effect and reduce the complexity of the data. Because the pulse shape depends on, not the distance but, the posture of the human, we take the echoes only and normalize the amplitude. The normalized signal is analyzed by the CLEAN algorithm.

### 3. Recognition by CLEAN Algorithm

When a human subject is illuminated by an UWB signal, the received signal can provide distinguishable information about the target. A complex subject shape returns multi-path components from different body parts at different times with various amplitudes. Therefore, the returned echo at an instant is composed of superposition of multiple returned scatters 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 is developed to detect a weak target in the presence of a strong target through subtracting the response of a strong target from the total response, in astronomy. It has been applied to the analysis of human scatters as well. Humans could be successfully classified among animals and vehicles [2, 3]. In our study, the CLEAN algorithm can estimate time-delay and amplitude of each scatter of the human body with the provided template waveform. The graduate student implemented the CLEAN algorithm using MATLAB to decompose the human echoes with the five template signals. An echo from a cylindrical reflector is used as a template signal. Through cross-correlation, the coefficients of the CLEAN algorithm are computed, resulting in five time-delays and five amplitudes. The iterations can be extended further to decompose more scatters, but we set the number of iterations to five because it is found to be sufficient empirically.

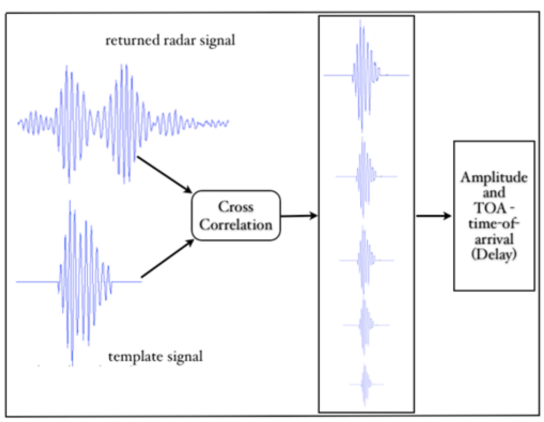
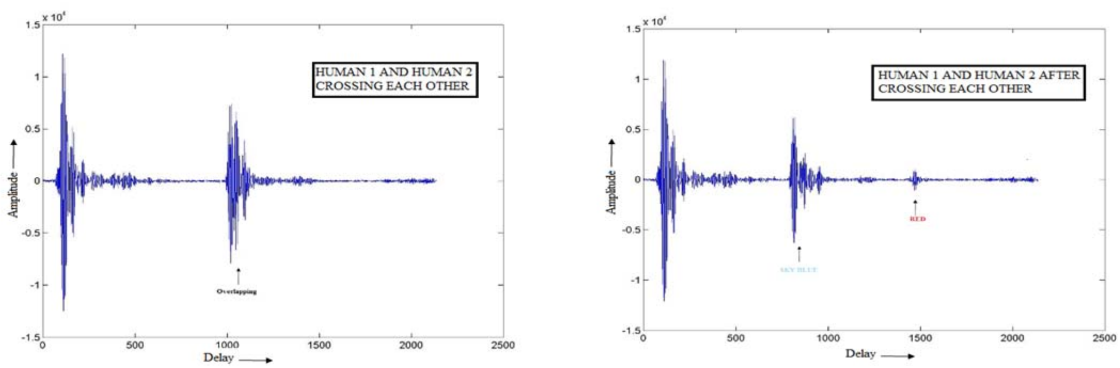



Figure 4: Concept of CLEAN algorithm

As a result, the estimated ten coefficients of the CLEAN algorithm correspond to a certain human posture. 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 signature of a walking style. We consider the mean and variance of CLEAN coefficients as a signature. Those are basic but contain significant information. Within the time window, the normalized echoes are analyzed by the CLEAN algorithm. We set the time window to 1.5sec. The mean and variance of the ten coefficients within the window are investigated for classification. Through calculating the similarity of features between before and after the echoes overlap, two human subjects could be successfully distinguished. The result is shown in Figure 5.




(a) (b)

Figure 5: Tracking result

## 4. Conclusion

We investigated the feasibility of solving the correspondence problem in multiple human tracking using the CLEAN algorithm based on human walking features. The signal obtained after reflection from the human subject is first pre-processed to remove the direct coupling and the background noise. The CLEAN algorithm uses the pre-processed human scatters to extract the feature of the return. The features are used for the classification in multiple human tracking. The suggested algorithm successfully classified the two humans. This project could provide an environment for the students to operate the UWB radar and to learn signal processing techniques including cross-correlation, normalization and the CLEAN algorithm. Three main learning outcomes are obtained through this project. First, students learned basic concept of UWB radar such as pulse repetition ratio and signal integration by operating the radar. Second, students understood the concept of the CLEAN algorithm to decompose UWB echoes. Third, students could implement a number of algorithms using MATLAB.

### References


[1] L.M. Frazier, “Motion detector radar for law enforcement,” *IEEE Potentials*, vol. 16, pp. 23 - 26, Jan. 1998.
[2] S. Chang, N. Mitsumoto and J. W. Burdick, “An algorithm for UWB radar-based human detection,” *IEEE Radar Conference,* pp. 1-6, May 2009.
[3] S. Chang, R. Sharan, M. Wolf, N. Mitsumoto and J. W. Burdick, “UWB radar-based human target tracking,” *IEEE Radar Conference*, pp. 1-6, May 2009.
[4] Jacob Bryan and Y. Kim, “Classification of human activities on UWB radar using a Support Vector Machine” *IEEE Antennas and Propagation Symposium,* Toronto, ON, July 2010.
[5] Jacob Bryan and Y. Kim, “Classification of human walking styles on UWB radar using a Support Vector Machine” *URSI National Radio Science Meeting*, Toronto, ON, July 2010.


### Biographical Information

**Youngwook Kim:** Young W. Kim received his BS degree in Electrical Engineering at Seoul National University, Korea, in 2003. He received an M.S. and Ph.D. degree in Electrical and Computer Engineering at the University of Texas at Austin, USA in 2005 and 2008 respectively. He is currently an assistant professor in the Department of Electrical and Computer Engineering at California State University at Fresno. His research interests are in the area of radar signal processing, antenna design and RF electronics. His primary topic of research lies in radar signal processing for the through-wall human monitoring using machine-learning techniques. Other topics of interest include wireless power transfer, development of fast algorithms for broadband antenna design, and equivalent-circuit modeling of broadband antennas. He was a recipient of the A.D. Hutchison fellowship from the University of Texas at Austin. He published around 26 technical papers, and holds two patents.

**Jagjit Singh:** Jagjit Singh is a graduate student of California State University. His research interests include RF electronics and radar signal processing.