Analysis of Micro-Doppler Signature Due To Indoor Human Motion Using Multilevel Fast Multipole Algorithm On GPU Cluster

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Detecting and tracking human motion in indoor environments are essential for both commercial (vital sign detection of elderly) and military applications (counter terrorism). Small variations in the carrier frequency caused by motion can be detected by Doppler radar systems. The micro-Doppler frequency shift depends on the transmitted frequency and the velocity of the different body parts over time. Different types of motions can be identified and classified from micro-Doppler spectrograms. Due to its bipedal nature, human micro-Doppler signature can be differentiated from others, including those caused by four-legged animals.

This paper analyzes the micro-Doppler signatures due to human motion in indoor environments. A joint time-frequency transform such as the Short-Time Fourier Transform (STFT) is performed on the received fields at the radar. A full wave model of human body using the Multilevel Fast Multipole Algorithm (MLFMA) (J. M. Song, C. C. Lu, and W. C. Chew, IEEE Trans. Antennas Propagat., vol. 45, no. 10, pp. 1488-1493, 1997) is developed in conjunction with the empirical Boulic model (R. Boulic, N. Thalmann, and D. Thalmann, The Visual Computer, Vol. 6, No. 6, 344-358, 1990) to characterize the human motion. Due to the large size of the problem, parallel programming techniques for MLFMA are developed for use on a GPU cluster.

MLFMA is the generalization of the single level Fast Multipole Method (FMM) and is based on grouping of groups in FMM. This method reduces the memory requirement of FMM from $O(N^{3/2})$ to $O(N\log(N))$, while the processing time also becomes $O(N\log(N))$ per iteration. Therefore, large-scale problems can be solved efficiently by MLFMA. The utilization of MLFMA for this application allows the calculation of the mutual coupling effects between different body parts and the indoor environment. The different human body parts are modeled by PEC canonical objects, such as ellipsoids and spheres. To describe their motion as human moves along his path, we use the Boulic model which is a standard analytical model extracted from empirical data. According to the Boulic model, the human body is described by 16 joints which reside at the end points of 17 body parts. The human walking signatures created by this model will be analyzed for different test cases such as different speeds and paths for the human.