Computer Modeling of the Doppler Signature of a Walking Human

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Using the Doppler spectrum of the radar response may offer the only solution for detecting moving targets concealed behind obstacles, such as vegetation or building structures. There is currently a great amount of interest in this technology, as demonstrated by several large-scale research and development efforts conducted by defense agencies in through-the-wall and foliage penetration radar sensors. The major challenge with this approach is that any moving objects (such as blowing leaves) or animals present in the scene can produce a Doppler response, thereby creating false alarms. In order to reliably discriminate human movers from other types of movers, we need to perform a more complex analysis of the Doppler signature by looking at temporal changes in the Doppler spectrum and extract features characteristic to a certain target. Moreover, such analysis may enable us to extract biometric features of a person (for instance, tall vs. short person, or weapon-carrier vs. non-weapon-carrier).

In this study we perform a time-frequency analysis of the Doppler signature of a walking human by creating Doppler radar spectrograms. We achieve this through high-fidelity computer models of a walking human and its radar signature. Although this kind of analysis has been performed by other researchers via computer simulations in the past, our approach involves more realistic human meshes and human motion, as well as accurate electromagnetic modeling of the radar signature. Additionally, by looking at various target configurations and radar parameters, we gain deeper insight into the phenomenology involved in this scenario.

Our simulations involve three steps. In the first step, we animate a high-resolution human mesh into realistic walking motion, using the Maya software package. The walking motion is decomposed into frames succeeding each other with the radar's pulse repetition frequency. In the second step we use an electromagnetic solver (such as FDTD or Xpatch) in order to compute the radar return for a given excitation pulse, for each frame. The time-domain pulses scattered by the human are processed through conventional I and Q channels, creating a sequence of complex samples that contain all the amplitude and phase information on the frame-by-frame radar return. We then take overlapping short-time Fourier transforms (STFT) on the I-Q data. The sequence of STFTs is arranged in a matrix format (with slow time variation by rows and frequency variation by columns) and the magnitude is plotted as a two-dimensional pseudo-color map, also known as spectrogram. We analyze several features of the Doppler spectrograms, separating the contribution of different body parts, and studying the variations with aspect angle, frequency and polarization. A clear understanding of the radar scattering phenomenology helps us with better data interpretation for the target classification problem.