# MicroDoppler Signature Simulation of Computer Animated Human and Animal Motions

Shobha S Ram* and Hao Ling
Department of Electrical and Computer Engineering
The University of Texas, Austin, TX 78712 U.S.A.

## Introduction

It is well known that non-rigid human motions give rise to time-varying Doppler features in the human radar return, called microDopplers [1, 2]. These features can be exploited for security monitoring applications such as perimeter control and through-wall tracking [3, 4]. However, one of the key issues is the capability to distinguish humans from other moving objects particularly animals. It has been reported that the microDoppler signature of a dog differs considerably from that of a walking human [3]. The difference mainly arises due to the difference between the animal quadruped motion and the human biped motion. However, a detailed analysis of the animal microDoppler has not been carried out.

In our paper we propose a technique for generating microDoppler signatures of human and animal motions using computer animation data available from motion capture technology. The main advantage of using motion captured data is that the radar returns can be easily simulated for different radar sensor parameters such as carrier frequency, sensor position, polarization, bandwidth etc. Additionally, the microDoppler from each body part of the human (or animal) can be studied in isolation to enable a detailed analysis of the microDoppler features. In order to demonstrate the validity of using computer animation data for generating microDoppler signatures, we first present simulation results of some human motions. These motions are next replicated in the laboratory and measurements are made using a Doppler radar and the Doppler spectrograms are generated. A comparison of the simulated and measured spectrograms is presented. Finally, the detailed microDoppler analysis of a galloping horse motion is presented.

## Methodology

We first present a brief description of the technique used to generate the microDoppler signature of human (or animal) motion from computer animation data. A more detailed description of the technique is presented in [5]. Computer animation data usually describe a skeleton structure of the human where the bones are connected through joints. Each joint is subject to translation motions along the X, Y and Z axes as well as rotation motions about the three axes (pitch, roll and yaw). By specifying the time-varying translation and rotation data for each joint of the skeleton, the animation motion of the human is described. After suitable algebraic operations on the data, the three-dimensional positions of all the bones of the body are obtained for each time instant. Next, the electromagnetic scattering from the human for each time snapshot is generated using a primitive-based prediction method similar to that described in [6]. Each body part associated with the bone is modeled as an ellipsoid whose radar cross-section (RCS) is computed as a function of its phase center, the aspect angle of the bone with respect to the radar, the dimensions of the ellipsoid and the carrier frequency. The dielectric properties of flesh are also incorporated in the calculation of the RCS. The time-varying RCS of the whole body is obtained by the complex sum of

978-1-4244-2042-1/08/$25.00 ©2008 IEEE

the RCS of all the body parts and applied in the radar range equation to derive the time domain radar returns. The Doppler spectrogram of the motion is generated by the application of the short-time Fourier transform on the simulated time domain radar returns.

## Simulation and Measurement Results

Some simulation results of human and horse motions are presented. The motion captured data of the human and horse motions were obtained from ACCAD Motion Capture Lab and Forge Studio Ltd, respectively. First, the Doppler spectrogram of human motion is simulated. Fig. 1a shows an animated human that walks at a fairly uniform speed and then jumps forward and then resumes walking at direct boresight towards the simulated radar. The microDoppler signature is simulated for a carrier frequency of 2.4GHz and presented in Fig. 1b. In the first three seconds, the microDoppler pattern shows the uniform human walking signature. The motions of the right and left limbs alternate. In each stride, the highest Doppler arises from the motion of the legs. The strongest returns are from the human torso. There is a noticeable variation in the Doppler pattern when the human jumps forward. The Dopplers from this motion are much higher. Also, the time between the motions of the right and left legs differ from the steady transition time during the uniform walking motion. Once the human has landed from the jump, the regular walking motion is resumed which is clearly reflected in the Doppler spectrogram in the final second. Next, the animation motion is replicated by a human subject in the laboratory with a Doppler radar operating at 2.4GHz. The spectrogram generated from the measured data is presented in Fig. 1c. From the figure, it is apparent that there is general similarity in the measured and simulated spectrograms. The steady stride motion is observed from 0 to 3s which is followed by the jump motion, after which the walking motion is resumed. The main difference observed in the measured and simulated spectrograms is caused by the difference in the exact motions used to generate the animation and the measured radar data. In addition, the negative Dopplers that are observed in the measured spectrogram arise from the IQ imbalance in the quadrature receiver of the Doppler radar. The simultaneous collection of motion capture data and radar data should be conducted to achieve a more quantitative evaluation.

Next, the simulation procedure is carried out for the animated galloping horse motion. The data specify the motions of 29 bones in the body of a horse as shown in Fig. 2a. The resulting spectrogram at 2.4GHz is shown in Fig. 2b. Due to the speed of the horse motion, the Dopplers are much higher than the human walking motion. Also, the Doppler spectrogram of a galloping horse is considerably different from the regular walking motion of a human in Fig. 1b. In order to enhance our understanding of the microDoppler spectrogram of the horse, the different body parts of the horse are studied in isolation in Fig. 2c through Fig. 2f. From Figs. 2c and 2d, it is observed that in the galloping motion, the forelegs and rear legs alternate with each other. The Dopplers from the torso and the head are strong but they show only slight bobbing variation. An additional microDoppler from the tail is also observed.

## Conclusion

A simple technique for generating the microDoppler signatures of complex human and animal motions from computer animated data has been proposed. The Doppler spectrogram of the quadruped motion of the horse shows considerable variation from the biped motion of the human. The microDopplers from the different body parts of the horse have been presented.

**Acknowledgments**

This work is supported by the National Science Foundation under grant CBET-0730924 and in part by a grant from the NSF Major Research Instrumentation Program.

**References**

[1] J. L. Geisheimer, E. F. Greneker and W. S. Marshall, "High-resolution Doppler model of the human gait," *SPIE Proc. Radar Sensor Tech. Data Vis.*, vol. 4744, pp. 8 – 18, July 2002.

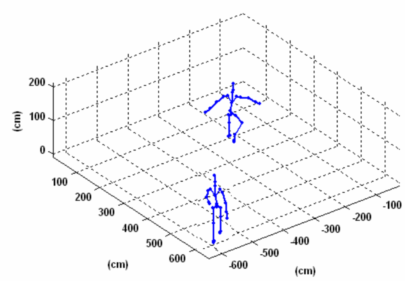
[2] V. C. Chen and H. Ling, *Time Frequency Transforms for Radar Imaging and Signal Analysis*, Artech House, Boston, MA, 2002.

[3] M. Otero, "Application of continuous wave radar for human gait recognition*,"* *SPIE Proc., Signal Processing, Sensor Fusion, and Target Recognition XIV*, vol. 5809, pp. 538 – 548, May 2005.

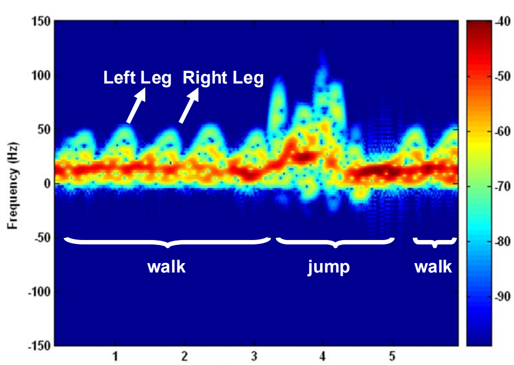
[4] M. D. Anderson and R. L. Rogers, "Micro-Doppler analysis of multiple frequency continuous wave radar signatures," *SPIE Proc.*, *Radar Sensor Technology XI,* Volume 6547, pp. 65470A, May 2007.

[5] S. S. Ram and H. Ling, "Simulation of human microDopplers using computer animation data," to be presented at *IEEE Radar Conf.*, May 2008

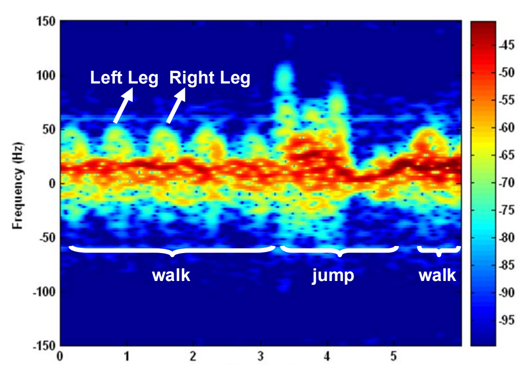
[6] P. van Dorp and F. C. A. Groen, "Human walking estimation with radar," *IEE Proc. Radar Sonar Navigation*, vol. 150, pp. 356-365, Oct. 2003.



**(a)**




**(b)**




**(c)**

Fig. 1. (a) Animation motion of human. Doppler spectrogram at 2.4 GHz of (b) simulated data, (c) measured data.

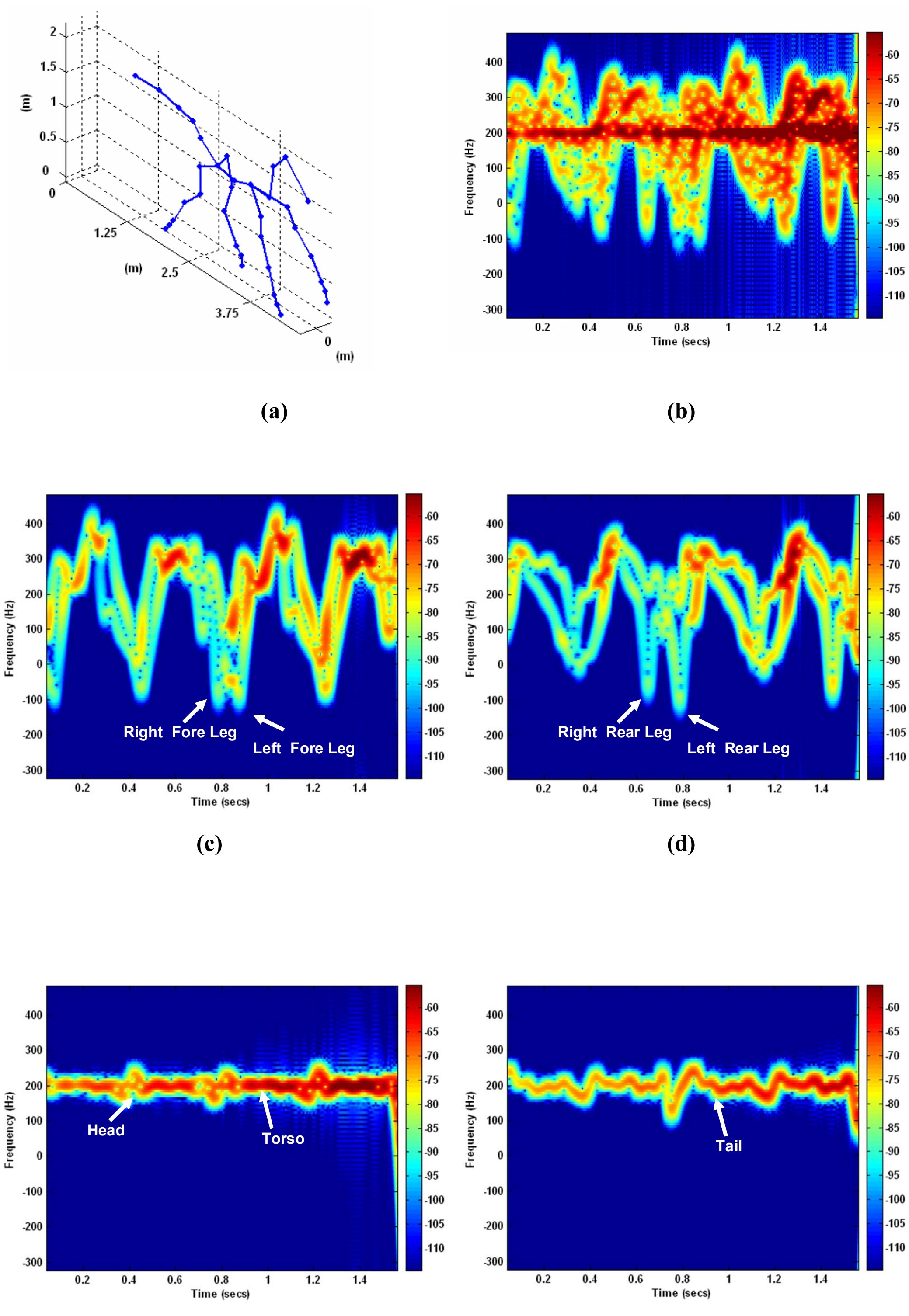



Fig. 2. (a) Computer animated galloping horse. Doppler spectrogram at 2.4GHz of the motion of: (b) galloping horse, (c) horse's forelegs, (d) horse's rear legs, (e) horse's torso and head and (f) horse's tail.