Development of a Closed Loop FMCW Radar Device to Extract Biometric Data for Security and Irregularity Detection

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Targeted Problem Statement / Hypothesis

Problem:

Decreasing processing time in biometric extraction from raw radar data while keeping signal integrity and security over wireless transmission

Hypothesis:

Implementing alternative transform methods can help to decrease processing times and ease data transmission and compression

Q1 - How can alternative transform methods be tested against each other and implemented to increase computation speed and accuracy?

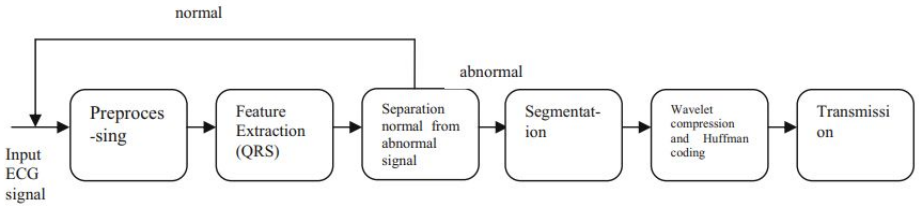
Time Frequency Analysis of Wavelet and Fourier Transform - Jarlton Wirsing (2020)

- Fourier Transform and its derivations are limited by lack of account for local features and frequency variation
- Wavelet Transform scales in time and frequency inversely
    - Many biometric signals (Heart Rate, Respiratory Function, etc.) are inconsistent in pulse rate and frequency
    - Available MATLAB implementation allows for easy testing

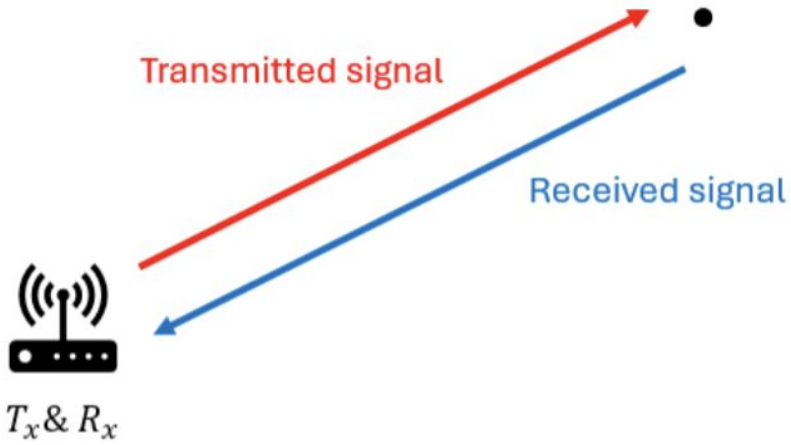
Q2 - How can radar-extracted biometric data be compressed and encrypted for secure transfer and storage?

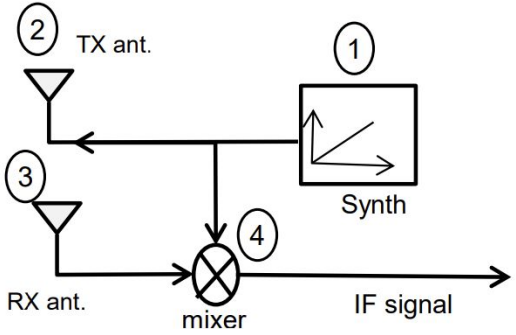
Compression and Encryption of ECG Signal Using Wavelt and Chaotically Huffman Code in Telemedicine Application

- Huffman encoding is a data compression technique done by creating binary trees based on symbol frequency
  - Higher frequency -> shorter code
- Considers huffman data compression of wavelet transformed-ECG data
  - Useful reference considering the use of wavelet transform and data transmission on health-rate data specifically



High-Level Proposed Approach / Experimental Design (Simulation)





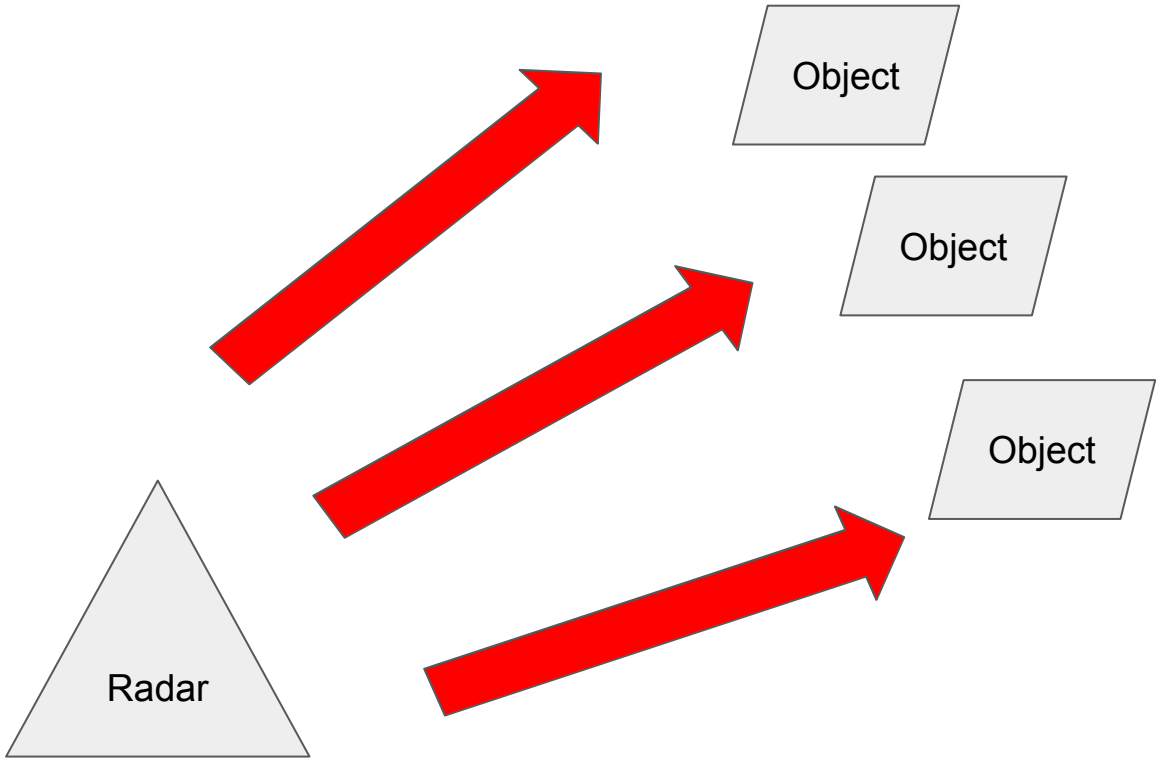
TX Chirp

$$S_{tx}(t) = \exp\left[j2\pi\left(f_c t + \frac{1}{2}\mu t^2\right)\right]$$

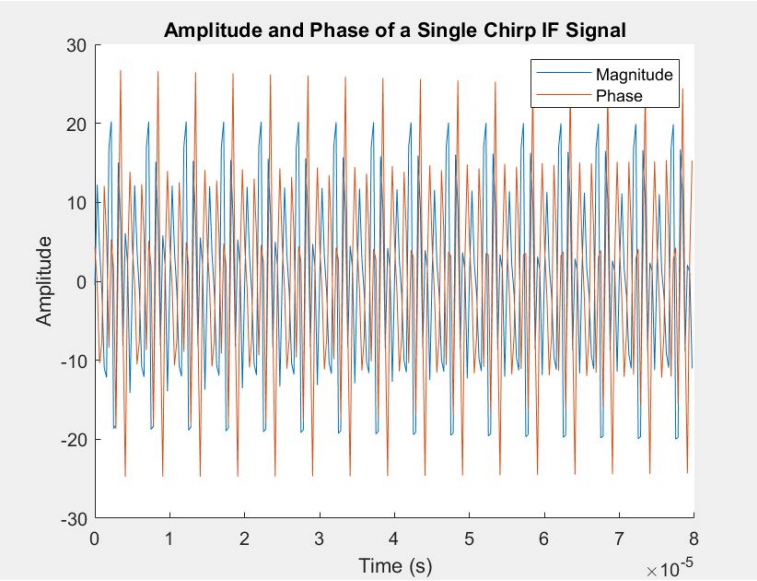
RX Chirp

$$S_{rx}(t) = \alpha \cdot \exp\left[j2\pi\left((f_c - f_d)(t-\tau) + \frac{1}{2}\mu(t-\tau)^2\right) + \omega_x\right]$$

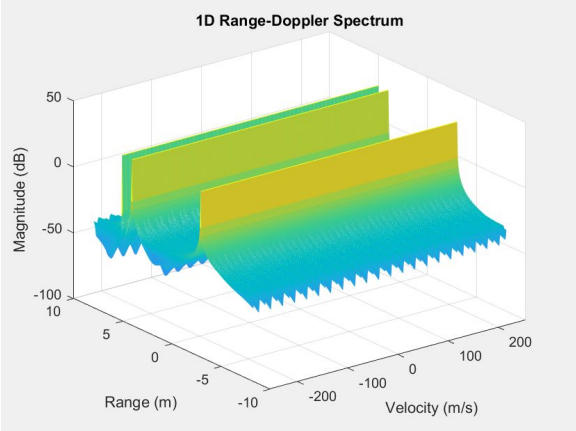
Simulation setup

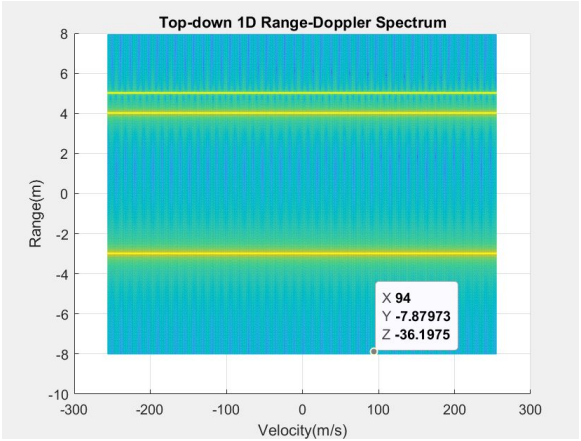


Simulation Processing and Intermediary Results

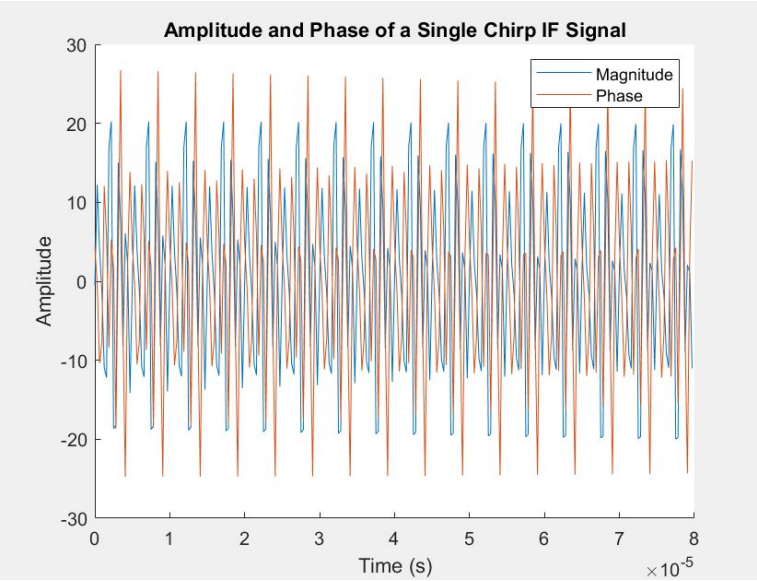


1-D FFT

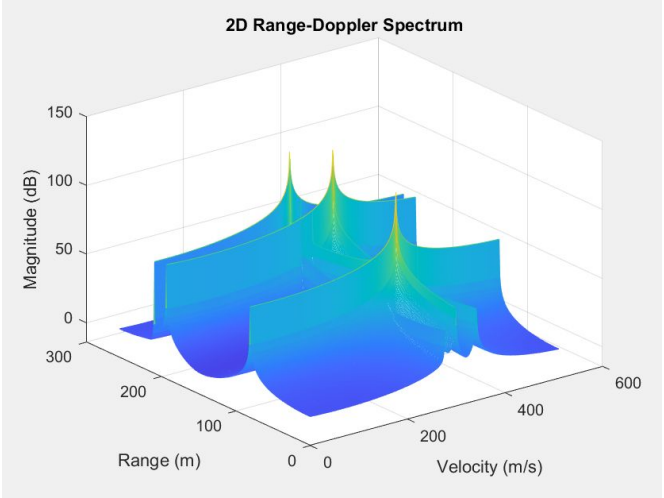


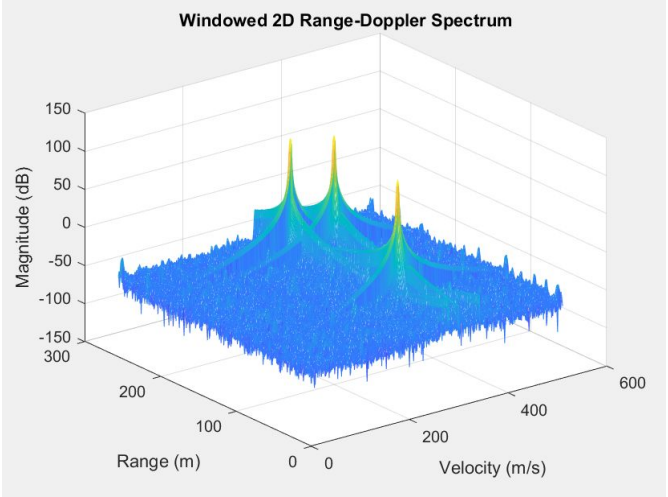


Simulation Processing and Intermediary Results



2-D FFT





Future Experimental Design

- Finish base signal decomposition algorithm
- Optimization of computation speed and accuracy
  - Test Fourier vs. Wavelet Transform
  - Potential use of Quantum Fast Fourier Transform (QFFT)?
- Testing on best encryption/transmission/storage methods to ensure security and persistence of necessary features
- Neural network for irregularity detection?

References

Rao, S. (n.d.). *Introduction to mmwave Sensing: FMCW Radars*. Texas Instruments. https://www.ti.com/content/dam/videos/external-videos/en-us/2/3816841626001/5415203482001.mp4/subassets/mmwaveSensing-FMCW-offlineviewing_0.pdf

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Wirsing, K. (2020, November 18). *Time frequency analysis of wavelet and Fourier transform*. IntechOpen. https://www.intechopen.com/chapters/74096