Velocity Tracking of Moving Objects Using Ultrasound
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Abstract
We develop and implement tracking algorithm to track the velocity of a mobile object using the Doppler Shift phenomenon. We use an ultrasonic transmitter and receiver pair to transmit and receive the signals. We first demonstrate feasibility of the project with a full simulation of a delayed and Doppler shifted signal, from which we track the position and velocity of the moving object using cross correlation methods. We then implement a physical system to transmit and receive the Doppler shifted signal. We use filtering and smoothing to reduce the noise on the received signal and then use the correlation method in frequency domain to find the Doppler shift. The measured Doppler shift is used to find the velocity of the object.

Overview
Goal
The goal of this project is to accurately determine the velocity of a mobile object using the Doppler shift phenomena as measured by ultrasonic sensors.

Approach
• Develop a Labview simulation which recreates the interaction between a standing transmitter and receiver pair:
  • Create an original signal and a Doppler shifted return signal
  • Allow variation of all parameters
  • Implement a Labview protocol that uses real ultrasound sensors to determine the velocity of a moving object.
• Transmit a sinusoidal signal at 40kHz
• Use filtering and smoothing in the frequency domain to find moving object’s velocity

Sampling Requirements
\[ N = \frac{f_s (v + v_s)}{f_0 (v_r - v_s)} \]
where:
\[ N \] : number of samples
\[ v_r \] : velocity of receiver
\[ f_s \] : sampling frequency
\[ v_s \] : velocity of transmitter
\[ f_0 \] : input signal frequency
\[ v \] : velocity of wave

These sampling requirements come from the constraints of our transmitter/receiver pair. We have a fixed sampling frequency, which means the only way to increase our data’s resolution is to sample for a longer period of time.

Simulation: Signal Generation
Inputs to Signal Generation .vi:
- Initial Distance (m)
- Velocity (m/s)
- Chirp Duration (s)
- Sampling Info (Sampling Frequency, Window Size)
- Original Signal Frequency (Hz)
- Distance from Transmitter to Receiver (m)
- Transmitter Amplitude
- Increase in Frequency during Chirp Signal (Hz)
- Signal Type (Currently, can choose between Sine and Chirp signals)

Simulation: Signal Processing
The initial and returned signals are received together. A fast Fourier transform is run on the data, and then a peak detection is used to determine the second highest peak in the desired range, which will be the Doppler-shifted signal. This is then reconverted into an estimated velocity.

Real Velocity Calculation
Initial testing showed signal from iteration to iteration has far too much noise to successfully determine the position of a mobile object using a Chirp signal. Using a Sine signal proved to be the only feasible means of deriving information, and even then we could only calculate the object’s velocity.

Formulation for Time Domain Doppler Shift
\[ t_e = \frac{1}{1 + 2|x_{\text{obj}} + vt_e|} \]

Sinusoid signal at \[ t_e = 2\pi f_{\text{dop}} \]
\[ t_e \] : time when receiver gets signal bounced from the mobile object
\[ t_b \] : is the time when signal bounces off the mobile object given by \[ t_b = \frac{v_s t_e - x_0}{v_s + v} \]
\[ v_s \] : velocity of the signal
\[ v \] : velocity of the mobile object
\[ x_0 \] : position of the platform at \[ t = 0 \]

Note: Amplitude at time \( t_e \) will be zero if \( t_e < \frac{2(x + vt)}{v_s} \)

References