1 Introduction

In this report a micro radar system is utilized for surface classification. Specifically, a radar sensor is placed on the inside of a robot facing downwards, with the objective of distinguishing if the surface below is made of grass and dirt or not.

2 Radar system overview

The radar system used for this project is a 60 GHz radar developed by Acconeer AB.

An antenna transmits a wavelet signal towards an object of interest. After a brief period of time a second wavelet signal is generated and *mixed* with data from a recieving antenna. This procedure is repeated, every time slightly delaying the generation of the second wavelet and thus mixing with a different section of the incoming pulse.

Throgh this methodology we can effectively produce

2.1 The radar principle

The radar principle is at its core simple. A wavelet pulse $x_T(t)$ with some carrier frequency Ω is transmitted towards an object of interest.

etc etc..

2.2 Matched filter

something something desired frequency response of the recieving antenna.

In any radar system a good Signal-to-Noise Ratio (SNR) is a highly desired property. Finding a reciever frequency response which maximizes SNR is thus an important topic. Denoting the reciever output as $y(t)$ and the incoming waveform as $x(t)$ the output spectrum will be a convolution of $x(t)$ and the system impulse response $h(t)$, or conversely a multiplication in the frequency domain $Y(\Omega) = X(\Omega)H(\Omega)$. If we seek to maximize SNR at some arbitrary point in time T_M the power at that very instant is

$$|y(T_M)|^2 = |\frac{1}{2\pi}\int X(\Omega)H(\Omega)e^{j\Omega T_M}d\Omega|^2. \quad (1)$$

Now we consider interference in the form of spectrally flat noise with power spectral density σ^2 W/Hz. The SNR ξ measured at time T_M can then be described as the ratio between the total signal power and the total noise power

$$\xi = \frac{|y(T_M)|^2}{(1/2\pi)\int|\sigma H(\Omega)|^2 d\Omega} = \frac{|(1/2\pi)\int X(\Omega)H(\Omega)e^{j\Omega T_M}d\Omega|^2}{(\sigma^2/2\pi)\int|H(\Omega)|^2 d\Omega} \tag{2}$$

which clearly depends on which reciever response is used. It can from above expression be shown [reference] that the maximum ξ is obtained when

$$H(\Omega) = \alpha X * (\Omega)e^{j\Omega T_M}, \text{ or} \tag{3}$$

$$h(t) = \alpha x^*(T_M - t) \tag{4}$$

where α is an arbitrary constant which has no impact on the resulting SNR. Examining $h(t)$ above we see that the optimal filter for maximizing SNR is when the coefficients consist of the transmitted waveform conjugated and time-reversed. This filter is called a *matched filter* due to the symmetrical relationship between waveform and impulse response.

One way of interpreting the matched filter is by viewing the filtering as a correlation. If we denote $\bar{x}(t)$ as the sum of both target and noise components the output $y(t)$ is given by

$$y(t) = \int \bar{x}(s)h(t-s)ds = \alpha \int \bar{x}(s)x^*(s + T_M - t)ds \tag{5}$$

which is recognized as the cross-correlation between noisy signal $\bar{x}(t)$ and transmitted waveform $x(t)$ evaluated at lag $T_M - t$. By shifting the constant lag T_M we then can obtain the full cross-correlation

2.3 IQ demodulation

A common type of data when working with radar signal processing is IQ-data (in- and quadrature phase). This type of data is useful in that it contains information not only about amplitude, but about the phase of the radar signal as well.

IQ-data is derived through a process commonly known as IQ- or quadrature-demodulation. For a mathematical deduction, the trigonometric identity

$$\cos(\alpha + \beta) = \cos(\alpha)\cos(\beta) - \sin(\alpha)\sin(\beta) \tag{6}$$

is used. Assuming the RF-signal received from the radar can be described as $s(t) = A(t)\cos(2\pi ft + \phi)$ it can be rewritten, using (6), as

$$s(t) = A(t)\cos(2\pi ft)\cos(\phi) - A(t)\sin(2\pi ft)\sin(\phi) \tag{7}$$

By means of low pass filtering, the following signal is then obtained

$$s_{lp}(t) = A(t)\cos(\phi) - A(t)\sin(\phi). \tag{8}$$

From this expression, the in-phase and quadrature phase (I and Q) are defined as $I(t) = A(t)\cos(\phi)$ and $Q(t) = A(t)\sin(\phi)$. Henceforth in this report, IQ-data will refer to complex numbers of the form $I + iQ$. Note that taking the absolute value of such a complex number yields the amplitude, A.

The above result is implemented in hardware according to figure (....). The RF signal is split up in two channels. In each of the channels it is mixed with a wave generated by an oscillator. In one of the channels, the generated wave is shifted 90 degrees. A low pass filter then shapes the final I- and Q-components

3 Feature selection

4 Classification

5 Discussion