3 – Time-domain Signal Analysis

Objective

The purpose of this exercise is to demonstrate some of the basic signal processing procedures that can be applied to experimental ultrasonic data, and also to get you familiar with dealing with a reasonably large volume of data.

Summary

You have been provided with an experimental ultrasonic dataset comprising 132 A-scans obtained as a transducer was scanned over an engineering component (the raceway of a large roller bearing) in an immersion tank in the NDE Laboratory at the University of Bristol. Your task is to extract the profile of the thickness of the component from the ultrasonic data. This is likely to involve filtering each A-scan to improve the signal to noise ratio, identifying reflected signals from the front and back surfaces of the component, measuring the time between them, and finally converting the time difference into a thickness value for that scan position. Because there are over 100 A-scans in the dataset, whatever procedure you develop will need to be automated.

Exercise 3

Open the relevant starter script `STARTER_bearing`. If you run it, it will load the relevant data and plot (1) an image of all the raw ultrasonic A-scans side by side and (2) an example of one of the ultrasonic A-scans. The raw data comprises the variables `time`, `pos` and `voltage` from a pulse-echo immersion test performed on a large steel bearing casing using a 5 MHz transducer. The variable `voltage` is a 2D 132x2000 array (Python) or a 2000x132 matrix (Matlab). The 132-long dimension is the position of the transducer and the other dimension is time. The transducer position (units: metres) associated with each time-trace is in the 132-element vector `pos` and the time axis (units: seconds) for the time-traces is given by the 2000-element vector `time`.

The signals present in a typical time-trace are the reflection from the outer surface of the bearing casing (at ~37 µs in the example signal that the starter script plots) and the reflection from the inner surface of the bearing casing (at ~51 µs). The maximum thickness of the component is known to be 55 mm.

Devise a procedure to automatically extract the thickness of the bearing case from a time-trace. Use this to produce a graph of the thickness of the component as a function of transducer position and estimate the thickness when the transducer position is 125 mm. Note that the data is quite noisy, so it will be advantageous to filter it. The functions, `fn_gaussian`, `fn_hanning`, `fn_hanning_band_pass`, `fn_hanning_lo_pass` and `fn_hanning_hi_pass` all provide functions that may be useful for filtering (or you can write your own).

Notes

The easiest way to digitally filter ultrasonic data is to perform a Fourier transform to convert it to the spectrum in the frequency domain, multiply the spectrum by a suitable filter function (e.g. one that suppresses high frequencies), and then inverse Fourier transform the filtered spectrum to obtain a filtered time-domain signal.