INTERNATIONAL CENTRE OF EXCELLENCE FOR EDUCATION IN MATHEMATICS

**Aircraft Response To Gusts**

**Hua Min Situ, School of Mathematical and Geospatial Sciences, RMIT University**

My project is on a design project, Aircraft Response to Gusts, from the DSTO. This report comprises a summary of work throughout the 6-weeks Vacation Scholarship.

The project aims to analyse the characteristics of a single channel of Normal Acceleration data and implement a simple filter on board the aircraft that removes manoeuvres from gusts using MATLAB. Specifically an aircraft experiences vertical acceleration which is measured at the centre of gravity when flying through a gust of wind. To keep the aircraft straight, the pilot induces some manoeuvre response. Acceleration due to gusts can vary significantly with aircraft weight and airspeed. The pilot keeps a manual report to distinguish between a manoeuvre he caused and an acceleration due to a gust as it is important to know how much gusts can cause undesirable vertical acceleration.

A sequence of measured acceleration values is given to be input, x(n), and it is made up of the three components, manoeuvres, gusts and noise. Assume noise is small.

The filtered acceleration values with gusts components with manoeuvres being removed is given to be output, y(n). Assume it is an Auto-Regression Moving Average model:

$$y(n) = a0x(n) + a1x(n-1) \ldots + aMx(n-M) - b1y(n-1) - b2y(n-2) \ \ldots - bBy(n-B)$$

My aim here is to determine the coefficients subject to the constraint that the filter must be stable. The desirable cut off frequency for this particular aircraft type was found by examining the Power Spectral Density of the signal as PSD allows me to observe the behaviour of the signal in different frequency range.

I start the design with a low-pass prototype and then apply a spectral transformation to convert it to a high-pass filter. This transformation is developed from the shifting and modulation properties of the DTFT.

Minimise transition width between manoeuvres and gusts. It is difficult to design a filter with a sharp transition edge as it would require higher order and can lead to instability, thus some manoeuvres will get pass. Cut off frequency lies in between passband frequency $\omega p$ and stopband frequency $\omega s$. Minimise overshoots thus passband ripple $\delta 1$ and stopband ripple $\delta 2$ must be small. Then calculate continuous edge frequencies from passband frequency $\omega p$ and stopband frequency $\omega s$. Find the order of filter from edge frequencies and ripple specifications. Using N to solve $\Omega c$, the cut off frequency in digital domain.

Using N and $\Omega c$ I obtained the coefficients for the high-pass filter then obtain the difference equation for the ARMA model.

A wider range of filters would need to be considered. For example, optimising the design of IIR filter using neural network. Another approach that could work if we had sufficient data available to the on-board aircraft system, would be to use airspeed, altitude and bank angle and assume the aircraft was doing a balanced turn, and compute the acceleration for that (manoeuvre) condition and subtract it from the measured acceleration.

I was able to produce a filter that meets the project specifications for this particular aircraft given its measured data. Specifically I derived a Butterworth Filter that was capable of having few parameters and small ripples implying lower computational complexity and hence less memory, CPU resources etc.  I also found MATLAB had quite a few high level commands which came in useful.

I developed a practical understanding of the process to work independently throughout the 6-weeks Vacation Scholarship and gained valuable experience in public speaking.

Hua Min received an ICE-EM Vacation Scholarship in December 2006.
See http://www.ice-em.org.au/students.html#scholarships2007