Special Topics in Radar F

Tracking Filter Engineering – The Gauss-Newton and Polynomial Filters

Dates: 29 February to 4 March 2016

Presenter: Dr Norman Morrison (University of Cape Town)

Course code: EEE5132Z

20 credit course

Course contents

The course provides a detailed introduction to tracking filter engineering based on the ***Gauss-Newton*** and ***polynomial filters***.

Background

At the start of the satellite age in 1958 and immediately thereafter, three tracking filters competed for acceptance at Bell Labs:

- Gauss-Newton filters were the first to be tried, but they had to be ruled out for near real-time use because of the speed limitations of the existing computers.
- The second to be tried were the Swerling filters which could be run in near real-time on the existing machines.
- Two years later the Swerling filters were replaced by the Kalman filters.

A number of facts were noted at that time, among them the following:

- The Swerling and Kalman filters yielded identical numerical results.
- The Swerling and Kalman filters both suffered from the same problems of unpredictable instability, and when the one became unstable so always did the other.
- The answer to their instability problems led to a degradation of their numerical accuracy.
- Absent the fact that they were unusable at the time, the Gauss-Newton filters were observed to be the best of the three – the Gauss-Newton filters were *unconditionally stable,* they produced *more accurate numerical results* and they were better suited to the tracking of *manoeuvring targets*.

The speed of today's computers is vastly greater than those of 1958, and so Gauss-Newton need no longer be ruled out for near real-time use.

The course

- Touches briefly on the Swerling and Kalman filters.
- Covers the Gauss-Newton filters in full depth.
- Covers the widely used polynomial filters which were devised by the lecturer when he worked at Bell Labs between 1964 and 1968.

Prerequisites

The topic of tracking filter engineering is unquestionably mathematical in nature. The course requires students to have a reasonably strong interest in mathematics, and also to be competent in computer programming.

The assumption is made that students have completed the following three under-graduate engineering mathematics courses (on which tracking filter engineering is based):

- Linear algebra
- Elementary statistics and probability
- Ordinary differential equations

The assumption is also made that students are willing, if need be, to review some of the material in the above three subjects.

The lecturer will do his best to refresh students' memories of these topics.

Course credit and final exam

Course credit will be based on

- A closed-book final exam
- A programming project

The problems on the final exam will all be taken from the down-loadable material that the lecturer has placed on the cloud (see either ***http://tinyurl.com/ndw59la*** or else ***http://bit.ly/MorrisonSSP****)*. The lecturer will draw the attention of the students to a number of problems during lectures, a subset of which will appear on the final exam. *(**Note:*** Complete solutions are included in the down-loadable material.)

Course textbook

Tracking Filter Engineering - The Gauss-Newton and Polynomial Filters

written by Norman Morrison and published by the Institution of Engineering and Technology (IET) , UK.

Course summary

Chapter 1: Introduction and overview

Chapter 2: Models, differential equations and transition matrices

Chapter 3: Observation schemes

Chapter 4: Random vectors and covariance matrices (background)

Chapter 5: Random vectors and covariance matrices in tracking filter engineering

Chapter 6: Bias errors

Chapter 7: Three tests for ECM consistency

Chapter 8: Minimum variance and the Gauss-Aitken filters

Chapter 9: Minimum variance and the Gauss-Newton filters

Chapter 10: Manoeuvring targets: The master control algorithms and goodness-of-fit

Chapter 11: The Kalman and Swerling filters

Chapter 12: The polynomial filters: Part 1

Chapter 13: The polynomial filters: Part 2

Lectures and demonstrations

There will be four lectures on each of Monday to Friday mornings, with a 10 minute break between each lecture. After a break for lunch the class will reassemble for approximately one hour during which time the lecturer will run demonstrations using the computer programs in the down-loadable material.