State Space Modelling for Ferromagnetic Detection

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This document aims to give a general overview of the problem of intelligent ferromagnetic detection, especially pertaining to the Metrasens product "Skout", a passive ferromagnetic security screening device. An attempt is made to formulate a simplified version of this problem in the language of state space models, and a roadmap outlining further improvements to this simplified approach is given.

1 Overview

Metrasens are developing a new class of ferromagnetic detection systems to provide greater capability in several markets, with urban security being a particular target. This new generation of systems is designed to not only detect the presence of ferromagnetic objects, but to discriminate threat items from benign objects carried by the general population: for example, a perfect system should ignore a mobile phone but raise an alarm for an assault rifle. The wide range of benign ferrous items carried day-to-day by the populace, in combination with the complex and varied nature of the potential threat items, make this a considerably difficult problem. In the simplest case, in which passive magnetometers are used to record the intrinsic ferromagnetic signature of the traversing items, there is a limited amount of information available to make this classification. Advanced signal processing and machine learning techniques are therefore being researched to enhance the performance to a satisfactory level, and it is believed that sequential Bayesian estimation techniques may a powerful technique to apply to this problem.

Though in principle these techniques might be applied to any of the new technologies in development, this project will focus on applying to these methods upcoming product named Skout. This technology utilises a set of magnetometers to measure the magnetic field ("B-field") passively produced by traversing ferrous objects. These can be measured over a window of time to produce a multivariate time-series (MTS), which is the basic data format to be input to an algorithm.

The basic idea for classification has been to "fit" the input MTS to a physical model, giving an intuitive, interpretable set of model parameters. These parameters can then be used to make a detection decision, likely strongly incorporating anomaly/outlier detection due to the unpredictable nature of the threat set and difficulty in collecting threat data. Including an intermediary space with interpretable parameters is believed to be crucial: only small datasets are able to be obtained, with potential heavy systematic bias in the threat sets especially, meaning that automatically learned or statistical features could be highly unreliable. Physical features help mitigate this, in theory, as only features which are intrinsic to the objects themselves (such as moment strength and object length) are sent to the classifier, and poorly understood abstract features are avoided.

The fitting step is currently being performed using the Levenberg-Marquardt technique to perform a non-linear least squares optimisation, minimising the residuals between the recorded MTS and a simulated traversal with a given set of model parameters. Although the global minimum of the objective function is typically being located correctly, this approach has a number of inherent shortcomings, which motivates the search for an improved inversion technique.

$$A = \begin{bmatrix} A_{11} & A_{21} \\ A_{21} & A_{22} \end{bmatrix} \tag{1}$$

1.1 Subsection

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Table 1: *Example table*

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First Name	Last Name	Grade
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Richard	Miles	5

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Figure 1: *A majestic grizzly bear*

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