MULTI-PLATFORM HYPERSPECTRAL TARGET DETECTION AND MODELLING IN DYNAMIC ATMOSPHERIC CONDITIONS

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by

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ABSTRACT

Target detection in remote sensing imagery, mapping of sparsely distributed materials, has vital applications in defence security and surveillance, mineral exploration, agriculture, environmental monitoring, etc. The detection probability and the quality of retrievals are functions of various parameters of the sensor, platform, target-background dynamics, targets' spectral contrast, and atmospheric compensation efficiency. A comprehensive approach to analyse the effect of atmospheric processes and target environment for the detection of an engineered target in hyperspectral imagery is critical for real-time remote sensing-based target detection systems. The overall aim of the thesis is to analyse target detection in hyperspectral imagery under the complex atmospheric and imaging environment. Under this overarching aim, the objective of this thesis is threefold. The first objective is to explore the different aspects of a radiative transfer model which is used for modelling the atmospheric parameters for atmospheric correction of remote sensing data. The second objective is to conduct an experimental analysis of the target detection systems with respect to target positioning and different background setting. Finally, we analyse the target detection performance under the influence of the various combinations of atmospheric conditions.

As part of the first objective, we have developed an open-end atmospheric correction scheme named Flexible Atmospheric Compensation Technique (FACT) based on open source Second Simulation of the Satellite Signal in the Solar Spectrum (6S) radiative transfer model (RTM). The proposed FACT scheme utilizes a look-up architecture for simulating the responses of the RT model for various input parameters' combinations. The proposed FACT scheme has been evaluated exhaustively using spatio-spectral statistical error measures by comparing the performance with widely used atmospheric correction models. Results confirm that the proposed FACT scheme offers accuracy of about 95% for hyperspectral imaging sensors and close to 98% for multispectral imaging sensors. To evaluate the target detection in complex scenarios and background conditions, we acquired a benchmark multi-platform hyperspectral and multispectral remote sensing dataset named as 'Gudalur Spectral Target Detection

(GST-D)' dataset. Positioning artificial targets on different surface backgrounds, we acquired remote sensing data by terrestrial, airborne, and space-borne sensors. Various statistical and subspace detection algorithms were applied on the benchmark dataset for the detection of targets, considering the different sources of reference target spectra, background, and spectral continuity across the platforms. We validated the detection results using the receiver operation curve (ROC) for different cases of detection algorithms and imaging platforms. Results indicate, for some combinations of algorithms and imaging platforms, consistent detection of specific material targets with a detection rate of about 80%.

Finally, we carried out a quantitative assessment of atmospheric parameters' influence on the detectability of engineered targets. Specifically, critical atmospheric parameters such as aerosol optical thickness (AOT), standard atmospheric profiles, and standard aerosol models are considered to quantify their influence on top-of-atmospheric (TOA) radiance signal. We formulated the radiance spectral library by simulating TOA radiance spectra using the 6S RTM. We have considered two cases of target radiance spectra simulation, i.e., (i) corresponding to a grid of different AOT values for a predefined atmospheric and aerosol profile, and (ii) corresponding to varying combinations of atmospheric and aerosol profiles at a given AOT. The detection results indicate that change in the magnitude of AOT across atmospheric models has decision-bearing implications on the overall accuracy. The selection of the wrong atmospheric profile can potentially aggravate the numbers of FAs produced by a detection algorithm.

The methodological approaches for designing an open-source atmospheric correction model and findings related to spectral target detection are the significant contributions of this thesis. The benchmark dataset generated in this work is a valuable resource for addressing intriguing questions in target detection using hyperspectral imagery from a realistic landscape perspective. Overall, the thesis provides an insight into why there is an impending demand for better atmospheric correction models, how the atmospheric variables are related to underlying problems of detecting engineered materials, and, finally, highlights the role of atmospheric modelling for target detection systems.