Framework to Unify Sensor Information for Observing Nature (FUSION): Selected Earth observation applications using remote sensing data

The thesis focuses on developing integrative frameworks for multi-sensor image fusion at pixel, feature and decision levels to aid information extraction. To meet this aim, different case studies were conducted across four major thrust areas, keeping in mind their relevance and application. Based on these thrust areas, the following objectives were formed: i) To assess the performance of pixel level fusion methods for very high resolution (VHR) images; ii) To develop decision level fusion method for multi-temporal images; iii) To generate decision level fusion method to improve the spatial resolution of thermal data using hyperspectral image; iv) To construct a feature level fusion framework for combining hyperspectral and LiDAR data.

The first objective spans over three case studies with images from VHR WorldView2 (WV2) sensor. The first study compares 12 Pan-sharpening (PS) algorithms and the following two synergistically uses multispectral (MS) and Panchromatic (Pan) bands (with or without PS) to map tree species as well as characterize moving objects. The first case study attempts to rank PS algorithms to find the ‘best’ method following application of 12 PS algorithms to VHR WV2 imagery. The second case study investigates the potential of VHR single-pass WV2 imagery for moving object identification and speed estimation. The time lag of fraction of a second between the data collected by MS and Pan bands of WV2 were used for detection of a fast moving aircraft. The third case study maps the spatial distribution of bamboo patches in parts of South 24 Parganas, West Bengal, India, applying both pixel based and object based approaches.

Potential of multi-seasonal Landsat data and ancillary GIS layers to map the LULC of complex urban areas characterized by spatial heterogeneity and dynamic land use patterns was explored under the second objective. The research establishes that composite annual maps from multi-seasonal satellite data can be derived with the aid of simple knowledge based decision rules. The formalization does not require preprocessing (atmospheric correction or radiometric normalization) of satellite data and a priori spatial information of the detailed LULC classes.

In the third objective, a series of experiments were designed to disaggregate LST derived from Landsat ETM+ thermal bands using narrowband reflectance information from EO-1 Hyperion hyperspectral sensor and three selected regression algorithms (partial least square, gradient boosting machine and support vector machine). The significance of this research is that it is the very first attempt to disaggregate LST using hyperspectral data which are assumed to be non-linearly related.

The fourth and final objective aims to classify tree species across different scales with multi-resolution hyperspectral and LiDAR data. This study bridges the existing knowledge gap by assessing the effect of scale on classifiers, input predictors and tree species composition. It also reinvestigates the assumption that LiDAR height information significantly influences tree species classification.

The key findings of this thesis indicate that the selected sensors have different types of information content and thus demand the use of diverse fusion frameworks. The frameworks developed can be extended to incorporate data from new sensors, such as Landsat 8 or soon to be launched missions, such as WorldView 3, Sentinel etc. Apart from new satellite data, it is desirable to test the applicability of these frameworks over larger geographical areas. The flexible control over parameters, as developed in this thesis, should enable generalization and extension of the research methodologies to other data and test sites.