FOREST FEATURE ESTIMATION USING MULTI-MODAL REMOTE SENSING AND SENSOR EXTRAPOLATION TECHNIQUES

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Abstract

The planned launch of the Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) mission in 2021 will enable the global exploration of likely earthquakes, volcanoes, and other significant geological events and will ideally lead to a new age of prediction for these occurrences. The mission, set to be divided into two orbitals, one with an on-board Interferometer Synthetic Aperture Radar system and the other with a Light Detection and Ranging system (LiDAR). Critical to the success of this mission will be the successful fusion of the several sensor modalities in order to accurately estimate the 3D vegetation structures and the dry biomass in areas where the sensors overlap. The objective of this study is to use measured datasets in conjunction with our remote sensor models to construct a feature estimation algorithm that is capable of fusing multi-modal remote sensing technologies with a minimal amount of ground information to yield an accurate estimate of forest structure including dry biomass and canopy height in areas with varying amounts of remote observations.

The BOREAS Southern Study Area (SSA) has been extensively studied. A ground campaign during the mid 1990s has yielded gigabytes of information including both field measurements as well as remotely sensed datasets. This study fuses L-band polarimetric AirSAR with SLICER LiDAR and Landsat optical datasets. Given the vastly differing footprints of the sensors, this study first develops a feature estimation algorithm for regions with overlapping coverage and then extends methods to regions of minimal overlap; particularly those regions lacking LiDAR measurements. The algorithm employs the normalized radar cross sections at three linear polarizations (HH,VV, and HV), the ratio between the LiDAR power return from a forest canopy compared to that of the ground, the LiDAR canopy height estimate, as well as multiple optical reflectances and the normalized difference vegetative index (NDVI) as its comparison features. These features are extracted on a pixel-by-pixel basis and compared to a database over 9,000 simulated forest stands. Each stand in the database was constructed using the Michigan Fractal Tree Generator and contains between 10 and 100 trees within a $100m^2$ area. These stands were then processed using the Michigan LiDAR simulator, the Michigan IfSAR simulator, and the Michigan Near IR Optical Simulator; each simulator has been validated to calculate the LiDAR, radar, or optical response of a fractal forest stand. Each pixel's measured features are compared to each database stand's features and using a maximum likelihood error function, the most similar database stand is selected. This study presents results comparing ground measurements to our selected database stand. When processing a $40{,}000m^2$ region within the BOREAS SSA, we achieved a height estimation root mean square error of 2.67 m and a biomass estimation error of $9.94kg/m^2$.

This study also presents a method to extend this model to regions lacking LiDAR measurements. In such regions, the available multi-modal remote sensing data are fused to estimate the LiDAR parameters used in this study. The estimated features are then fed into the existing algorithm along with the measured data sets' features and in a region of $212{,}100\ m^2$, we achieved a height estimation root mean square error of $3.97\ m^2$.

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