Abstract

In the last decade the increasing availability of high resolution remote sensing data enabled precision forestry, which aims to obtain a precise reconstruction of the forest at stand, sub-stand or individual tree level. This calls for the need of developing techniques tailored on such new data that can achieve accurate forest parameters estimations. Moreover, in this context the integration of multiple remote sensing data brings to a more comprehensive representation of the forest structure. Accordingly, the goal of this thesis is the development of novel methods for the automatic estimation of forest parameters that can exploit the different properties of multiple remote sensing data sources. The thesis provides five main novel contributions to the state-of-the-art.

The first contribution of the thesis addresses the problem of the single tree crowns segmentation in multilayered forest by using very high-density multireturn LiDAR data. The aim of the proposed method is to fully exploit the potential of these data to detect and delineate the single tree crowns of both dominant and sub-dominant trees by a hierarchical 3-D segmentation technique applied directly in the point cloud space. The second contribution of the thesis regards the estimation of the diameter at breast height (DBH) of each individual tree by using high-density LiDAR data. The proposed data-driven method extensively exploits the information provided by the high resolution data to model the main environmental variables that can affect the stems growth in terms of crown structure, topography and forest density. The third contribution of the thesis proposes a 3-D model based approach to the reconstruction of the tree top height by fusing low-density LiDAR data and high resolution optical images. The geometrical structure of the tree is reconstructed via a properly defined parametric model which drives the fusion of the data. Indeed, when high resolution LiDAR data is not available, the integration of different remote sensing data sources represents a valid solution to improve the parameter estimation. In this context, the fourth contribution of the thesis addresses the fusion of low-density airborne LiDAR data and terrestrial LiDAR data to perform localized forest analysis. The proposed technique automatically registers the two LiDAR point clouds by using the spatial pattern of the forest in order to integrate the data and to automatically estimate the crown parameters. The fusion of the LiDAR point clouds leads to a more comprehensive representation of the 3-D structure of the crowns. Finally, we introduce a sensor-driven domain adaptation method for the classification of forest areas sharing similar properties but located in different areas. The proposed method takes advantage from the availability of multiple remote sensing data to detect features subspaces where data manifolds are partially (or completely) aligned.

Qualitative and quantitative experimental results obtained on large forest areas confirm the effectiveness of the methods developed in this thesis, which allow an improvement in terms of accuracies when compared to other state-of-the-art methods.

Keywords: LiDAR, high resolution optical images, hyperspectral images, data fusion, image processing, signal processing, classification, estimation, remote sensing, forestry.