FUSION OF HYPERSPECTRAL AND LIDAR REMOTE SENSING DATA FOR THE ESTIMATION OF TREE STEM DIAMETERS

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1. INTRODUCTION

The study of forests and their biophysical parameters is an important task that has many implications in many different fields (e.g., economy, environment). In particular, forests are an important source of information for studies related to climate change; a detailed knowledge of forests allows one to have also detailed knowledge on carbon exchanges and stocks. These studies have became of great importance in these last years due to the rules of the Kyoto protocol, and to others environmental protocols that require that each nation provides an estimate of the CO_2 stored and exchanged by its forests. In this context, it is important to study the parameters of the trees and forests, like the height, the stem volume, the basal area, the diameter at breast height (DBH) of the trees, etc.

In this study, we focus our attention on the DBH, as it can be used for the estimation of various parameter of the tree (e.g, stem volume, biomass volume, etc), and because it can be measured easily with a certain precision from the ground allowing us to have a reliable ground truth. Two kinds of remote sensing data that are widely used in the literature for the study of forests are hyperspectral and LIDAR ones. Usually, hyperspectral data are mainly used in the classification analysis, while LIDAR data are mainly used for the estimation of biophysical parameters. Concerning the estimation of stem diameters some studies exist in the literature (e.g., [1]), and they are mainly based on LIDAR data. At the present, from our analysis, no significant studies exist on the possibility to retrieve a rough estimate of stem diameters with hyperspectral data.

The goal of this paper is to analyze the combined use of hyperspectral and LIDAR data in the estimation of tree stem diameters. In particular we considered these data separately and combined. Moreover, we aim at analyzing if the information content of hyperspectral data can be exploited for obtaining a rough estimation of stem diameters. This issue is very interesting as hyperspectral data are widely used for the classification of forest areas, and thus it is interesting to understand if they can be used also to estimate physical parameters of the trees.

2. ARCHITECTURE OF THE PROPOSED SYSTEM

In Figure 1 the architecture of the proposed system for the estimation of stem diameters is shown. It can be divided into four main blokes: i) data preprocessing; ii) segmentation; iii) variables extraction and selection; and iv) estimation.

Concerning LIDAR data, in the preprocessing phase the raw point cloud was rasterized, and the Digital Elevation Model (DEM) of the area was subtracted to the elevation information. This process allowed us to obtain the height of each pixel with respect to the ground. Regarding the hyperspectral data, some images were mosaiked in order to cover the whole area analyzed, and before that a radiometric normalization was applied to each image in order to obtain a uniform mosaic. The hyperspectral mosaic was de-noised with a low-pass filter.

In the segmentation step, each tree in the scene was identified and a region was drawn around the crown of the identified trees. The segmentation was performed on the Digital Canopy Model (DCM) derived from the first return LIDAR elevation, using a segmentation algorithm especially developed for crowns extraction in LIDAR data. This algorithm takes into account both the diameter of the crown and the range of the values among the crown [1].

From each crown a series of variables were extracted from both the LIDAR and hyperspectral data. Concerning the LIDAR data, we considered the mean, the maximum, the minimum, the standard deviation, the skewness, the kurtosis, and the percentiles of each return. Concerning the hyperspectral bands, we considered the mean value among the crown for each band.

All these variables were then selected using a stepwise variable selection. No predictor variable was left in the model with a partial F statistic with a significance level higher than 0.05.

The estimation was performed using a standard linear multivariate regression and a Support Vector Regression (SVR) with two different kernel functions (linear and Gaussian RBF). The SVR technique showed to be particularly effective in the estimation problem in many different domains (e.g., [2]), in particular in situation characterized by independent variables with different distribution.

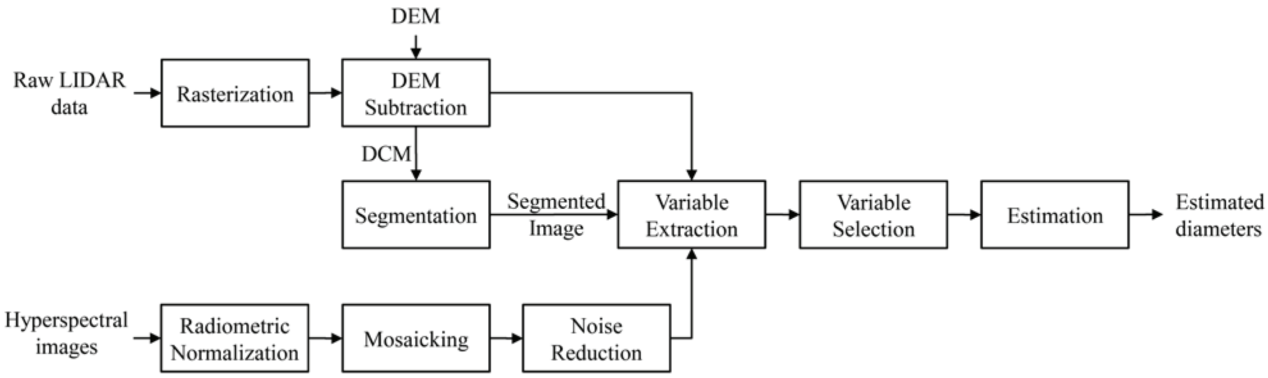

Figure 1. Architecture of the proposed system.

3. EXPERIMENTAL RESULTS

The study site selected for our experiments is a mountain area in the Trentino region in Italy. It is characterized by a varied morphology, and by the presence of about twenty different tree species. On this area, we collected the position and the diameters of 178 trees, distributed among the whole site and belonging to almost all the tree species present in the area. These points were then divided into three sets (training, test, and validation sets).

The LIDAR data were acquire with an Optech ALTM 3100EA and the data acquired are characterized by four returns and a very high posting density (more than 8 points per square meter). The hyperspectral data were acquired with an AISA Eagle sensor in 63 spectral bands from 400 [nm] to 990 [nm], and with a spatial resolution of 1 [m]. To cover the whole study area four images were taken.

Table I shows an example of the results obtained on the test and validation sets with a linear SVR for the estimation of tree stem diameters. As it is possible to see, the combined use of hyperspectral and LIDAR data allows one to increase the performance, with respect to use only LIDAR or hyperspectral data. This last kind of data provided lower accuracies respect to the LIDAR ones, but the results are still interesting as they point out a correlation between the stem diameters and the spectral signature measured by hyperspectral sensors. This is very important as the acquisition of hyperspectral data is much less expensive than LIDAR ones, and these data are also useful for classification purposes. Additional results and discussion will be reported in the full paper.

TABLE I. ESTIMATION OF TREE STEM DIAMETERS OBTAINED WITH A LINEAR SVR.

Variables used	Test		Validation	
	MAE (cm)	NRMSE (%)	MAE (cm)	NRMSE (%)
LIDAR	4.59	14.1	5.54	15.2
Hyperspectral	6.54	20.0	7.18	19.4
LIDAR + Hyperspectral	4.15	13.2	5.20	14.4

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