LiDAR-based 3D Mapping of Forests

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Introduction

The contribution highlights new methods for detection of forest objects like single trees and dead trees using methods from machine learning and computer vision. Experiments were conducted in the Bavarian Forest National Park to extract forest parameters from ALS full waveform LiDAR data and aerial imagery on a large forest area. The LiDAR data were captured in leaf-off and leaf-on situation with the Riegl LMS Q-860i scanner at a point density of 30 points/m^2. A waveform decomposition using the sum of Gaussian functions generated 3D points clouds. Multispectral airborne data were acquired with the DMC camera at a GSD of 20 cm. Moreover, TLS data were captured in small area plots by a Riegl LMS-Z390 scanner.

Single tree detection

A 3D segmentation technique based on Normalized Cut automatically retrieves tree parameters like tree position, tree height, crown diameter and crown base height on a large scale. A binary logistic regression classifier is trained with the underlying point cloud data to estimate the parameters of the similarity function and to replace the static stopping criterion. Thereby, effects of under segmentation and over segmentation can be efficiently reduced (Amiri et al., 2016b). For comparison, DSM data were calculated with dense matching techniques implemented in two commercial packages (SURE, MATCH-T). In case of dominating trees the accuracy of single tree extraction from LiDAR point clouds and airborne data is almost similar. However, the detection accuracy of single trees from aerial data deteriorates significantly in the medium and lower forest layers.

Tree species classification

A large set of different features were calculated from the ALS data and the MLS data. The ALS data provided geometric features (Axis length of fitted paraboloids to the tree crown; height and density dependent frequencies in tree clusters; ratios of single, first and middle points), radiometric features (Histograms of intensities and pulse width) and bag-of-words models based on the local covariance matrix in varying spherical neighborhoods. Gabor features, Haralick features (GLCM), and channel means and covariances were computed from the MLS data. The large feature set was combined in different groups and reduced by a forward stepwise feature selection and a logistic regression classification with L1-regularization. Just using the MLS imagery leads to a low overall accuracy of 54%. If the full ALS feature set is used the six tree species (European beech, Norway spruce, Silver fir, Common rowan, Sycamore maple, European white birch) can be classified with 69%. The best result with 73% accuracy is achieved by combining GLCM and the full ALS feature set (Amiri et al., 2016a).

Detection of standing trees with tree crown

This new method classifies standing dead trees still holding the rest of a tree crown with ALS data and aerial CIR images. The 3D segments from the tree detection method are re-projected into the images yielding enclosing polygons. The means of the red, green and IR channel and the six independent elements of the covariance matrix are extracted to train a binary classifier. The analysis of 500 labeled objects reveals a detection rate of 89% (Polewski et al., 2015b; Polewski et al., 2016a).

Detection of standing trees without tree crown

Dead trees without a tree crown are classified solely from ALS Data since these snags are not visible in CIR-images. The key idea is to characterize the snags by free 3D shape contexts. Their advantage is that cluttering effects resulting from small trees and bushes can be significantly reduced. The fairly high feature space is scaled down by a genetic algorithm. Experiments with about 400 labeled objects verify a detection rate of 90% (Polewski et al., 2015c).

Detection of fallen trees

This section presents a new method to detect fallen trees from ALS and TLS data. In both cases a DTM and potential stems points are classified using point feature histograms and covariance-based features. In case of ALS data a context-based classification with Conditional Random Fields yields single stem segments (Polewski et al. 2017a: Polewski et al. 2015a). The unary terms are formed by the log-likelihoods of the point-based shape appearance and the centrality which is based on the spatial configuration of neighbouring segments. The pairwise terms are defined by the log-likelihoods of the collinearity and the spatial overlap of segment pairs. This classification filters out the most appropriate stem segments candidates from a huge number of segment candidates. Finally, the classified single stem segments are fused by the normalized cut segmentation whose similarity function and stopping criterion are learned from a physical simulation of fallen trees. Numerous scenarios of fallen dead trees are generated which train a logistic regression as a binary classifier. The accuracy tested in two coniferous plots and three deciduous plots ranges between 81% and 92% for correctness and 51% and 86% for completeness.

If TLS data are available the method can be simplified since the stem shape are fairly good represented by the high point density. Thus, it is sufficient to segment the potential stem points from the point classification by a connected component segmentation and to subsequently find the stem segments via a novel cylinder fitting method (Polewski et al. 2016b; Polewski et al. 2017b). Finally, the single stem segments are merged again with the normalized cut segmentation. The tested accuracy ranges for three small plots between 70% and 80%.

Conclusions

The contribution shows that large forest areas can by fully automatically processed with LiDAR data to generate a 3D tree mapping. Especially, fallen and standing dead trees can be succesfully detected by methods from machine learning and computer vision.

Literature

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