Geophysical Research Abstracts
Vol. 13, EGU2011-10351, 2011
EGU General Assembly 2011

Manning's n determination using vertical vegetation structure based on dense airborne laser scanning data

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Laser Scanning, often referred to as LiDAR, is used as a fast and accurate technique to collect topographic Earth information. For capturing terrain data Airborne Laser Scanning (ALS) became a state-of-the-art data source. ALS is a time and cost-effective method to acquire topographic data with a low amount of user interaction, a high ground sampling density (typically 1-50 points per square meter) and a height accuracy of less than 15 cm (worse for steep slope areas). It is used for area-wide 3D data acquisition in support to a range of scientific disciplines like archaeology, geology, geomorphology, hydrology and many more.

Hydrology and water management will mostly benefit from technological and scientific advances in airborne, mobile and terrestrial laser scanning, by high precision topographic data acquisition. It is an ongoing trend that sensor weight and size will continue to decrease successively while functionality (full-waveform, multiple pulses in the air, two wavelengths, on-line radiometric calibration, increasing sampling density, decreasing vertical resolution etc.) and usability does further improve. Because laser pulses can penetrate the vegetation canopy only through gaps, a very dense ALS data set is needed to determinate vertical vegetation structure parameters. Dense laser scanner data provide both precise geometric and high vertical resolution allowing an improved 3D surface classification for hydraulic roughness map calculation.

The roughness of the terrain and the type of vegetation (trees, shrubs or grasses) has a strong effect on the flow regime. Thus, hydraulic models need to parameterize the effect of roughness through the use of hydraulic friction coefficients such as the Manning's n or the Chézy coefficient. The state-of-the-art in hydraulic roughness parametrization is to use land cover maps derived from areal images and/or field trips, and to select for all land cover class representative roughness values that yield the most realistic flood inundation patterns. As highlighted in different studies this method is not optimal because of shortcomings in the model scheme, computation method or model input may be compensated using roughness values that are physically not representative.

In this contribution the complexity of vertical vegetation structure has been analyzed based on dense ALS point cloud data to develop a model for Manning's n determination. Using the original 3D ALS point cloud a voxel structure is used to count the points within each voxel. In general it is assumed, that the occurrence of points within a voxel is an indicator for elevated objects and consequently for increased roughness. Therefore, vertical connected voxels that are occupied with at least one point are merged to connected vertical structures, whereas a height threshold is applied to skip areas that are not illuminated by laser shots. For each voxel and connected vertical structure the height range and various statistical measures are calculated. Based on these derived statistical parameters a function is developed to assess the Manning's n value per cell. The assessed Manning's n values are used as input in a 2D hydraulic model. The result is compared and evaluated with a 2D model output of traditional derived roughness coefficient map. The results show the large potential of using the entire vertical vegetation structure for hydraulic roughness estimation.