Limits and potentialities of gridded LiDAR data in the forest context: the case of the new Piemonte Region dataset

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Abstract

Aim. LiDAR technology (*Light Detection and Ranging*) is suitable for a large variety of applications in monitoring and studying forestry resources. LiDAR is increasingly used in qualifying the forest to rationalize its exploitation (biomass), management (also from an environmental protection point of view) and for describing its role as ecological indicator in the climate change context. Therefore, a rigorous validation of measurements from these systems, more frequently available for users from institutional subjects and not, it is required. This work is aimed at evaluating the quality of the LiDAR dataset acquired during the 2009-2011 aerial survey over the entire Piemonte Region (Italy). These data has been recently made available for free by the regional cartographic department. Data are supplied to users in raster format: both DTM (*Digital Terrain Model*) and DSM (*Digital Surface Model*) are available. In this work a traditional statistic approach is performed together with geostatistical analysis to explore and describe main data uncertainty factors looking for its possible dependence from terrain morphometry.

Materials and methods. The analysis focused on 17 sample areas concerning 19 municipalities of the Piemonte Region describing three territorial contexts: mountain, hill and lowland. Each context consists of a variable number of sections whose size matches the one of the correspondent section of 1:10,000 Regional Technical map. Available data are supplied as raster DTM and DSM, pre-processed from the original LiDAR acquisition by a filtering and regularization process. DTM and DSM geometric resolution after regularization is 5 m. The 4 level DTM has a declared altimetry precision of +/-0.3 m and planimetric one of +/- 0.3 m. Additionally the correspondent digital RGB (true color) and VNIR (false color) orthoimages were obtained. LiDAR clouds have been acquired by LEICA LS50-II sensor. The nominal geometric resolution of orthoimages is +/-0.4 m (Regione Piemonte 2012).

This work focused on three issues: a) CHM (*Canopy Height Model*) errors (negative values) analysis obtained by DSM and DTM differencing (results are referred to 5% of points); b) analysis of the error affecting the DTM/DSM measurements in the overlapping areas between adjacent sections (results regard 20% of points); c) co-registration analysis of orthoimages and DSM; this is an important factor mainly when mapping tree position from orthoimage photointerpretation or object based classification (e.g. Treeline mapping). For a) and b) a correlation analysis was made to investigate if any relationship between error and terrain morphometry exists. Particular attention was paid to slope factor, considered, from literature, the more conditioning one. Moreover a geostatistical analysis was performed by variogram to measure and qualify the spatial autocorrelation of errors. SAGA GIS and IDL programming tools were used for this tasks.

Results. The analysis showed some errors concerning CHM, probably due to a not perfect co-registration between DTM and DSM, or to a lower accuracy of the original data respect to the declared one (uncertainty can be introduced during the regularization process of the LiDAR cloud). In fact, CHM presents not negligible negative height values of canopy (or objects), higher than the declared precision value of 0.6 m. The following percentages with respect to the three explored contexts were obtained: lowland = 0.34 %, hill = 1.28 %, mountain = 12.24 %.

A strong conditioning by terrain morphometry (slope) to CHM error was found, especially concerning the maximum committable error (MCE). An exponential and a parabolic regression model was found for MCE respectively in the mountain and hill context. No correlation instead affected CHM errors in the lowland context. To better focus this issue a sample section representing the mountain context was selected (Carema municipality) and CHM error variograms were calculated, demonstrating once more the strict dependency of CHM errors from topography.

Analysis concerning errors affecting DTM/DSM in the overlapping areas between adjacent sections (somehow defining the degree of co-registration and geometric coherence between heights representing the same points but belonging to different DTM/DSM sections) showed that some differences (errors) were present. In fact, statistics showed that the declared precision threshold (0.6 m) was overcome in the following percentages (before DTM, after DSM): 17.5% and 22% in the mountain context, 1.8% and 8.8% in the hill context, 0.3% and 1.7% for the lowland context. Correlation analysis comparing error and slope demonstrated that no correlation is present for this type of error.

As far as co-registration between DSM and orthoimages is concerned no final result can be given here as this part is currently in phase of verification through photointerpretative process. First results suggest a displacements between canopies from DSM and canopies mapped form orthoimages; these are not always negligible despite of the low resolution

of DSM (5 m) respect to the one of orthoimage (0.4 m). Furthermore this displacement seems to be correlated to a joint effect of the geometry of the acquisition of the aerial image and topography of the area.
We can say that results pointed out the existence of anomalies related to CHM (negative values) whose value exceeded, above all in the mountain context (highly moved areas), the data nominal precision and that errors are correlated to ground morphology, in particular to slope steepness. Tests conducted on overlapping zones between neighboring sections showed that there is not perfect coherence between adjacent DTM/DSM sections. This effect increases from lowland to mountain areas. However, in this case no correlation with specific morphometric elements was observed. Several preliminary tests showed that, in spite of significant difference between the respective geometric resolution, no perfect overlap is present between orthoimages and correspondent DSM. Again, this appears more evident for the mountain context; this condition seems to suggest the lack of application of a precision orthoprojection process during the ortoimages generation. However more tests are requested.

Bibliography Regione Piemonte (2012), Produzione di supporti topografici per la pianificazione a livello locale nella Regione Piemonte, Relazione MDE Blocco 03.