Geophysical Research Abstracts
Vol. 16, EGU2014-15030, 2014
EGU General Assembly 2014

Building a LiDAR point cloud simulator: Testing algorithms for high resolution topographic change

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Terrestrial laser technique (TLS) is becoming a common tool in Geosciences, with clear applications ranging from the generation of a high resolution 3D models to the monitoring of unstable slopes and the quantification of morphological changes. Nevertheless, like every measurement techniques, TLS still has some limitations that are not clearly understood and affect the accuracy of the dataset (point cloud). A challenge in LiDAR research is to understand the influence of instrumental parameters on measurement errors during LiDAR acquisition. Indeed, different critical parameters interact with the scans quality at different ranges: the existence of shadow areas, the spatial resolution (point density), and the diameter of the laser beam, the incidence angle and the single point accuracy.

The objective of this study is to test the main limitations of different algorithms usually applied on point cloud data treatment, from alignment to monitoring. To this end, we built in MATLAB(c) environment a LiDAR point cloud simulator able to recreate the multiple sources of errors related to instrumental settings that we normally observe in real datasets. In a first step we characterized the error from single laser pulse by modelling the influence of range and incidence angle on single point data accuracy. In a second step, we simulated the scanning part of the system in order to analyze the shifting and angular error effects. Other parameters have been added to the point cloud simulator, such as point spacing, acquisition window, etc., in order to create point clouds of simple and/or complex geometries.

We tested the influence of point density and vitiating point of view on the Iterative Closest Point (ICP) alignment and also in some deformation tracking algorithm with same point cloud geometry, in order to determine alignment and deformation detection threshold.

We also generated a series of high resolution point clouds in order to model small changes on different environments (erosion, landslide monitoring, etc) and we then tested the use of filtering techniques using 3D moving windows along the space and time, which considerably reduces data scattering due to the benefits of data redundancy.

In conclusion, the simulator allowed us to improve our different algorithms and to understand how instrumental error affects final results. And also, improve the methodology of scans acquisition to find the best compromise between point density, positioning and acquisition time with the best accuracy possible to characterize the topographic change.