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3D point cloud classification of complex natural scenes using a multi-scale dimensionality criterion: applications in geomorphology

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3D point clouds derived from Terrestrial laser scanner (TLS) and photogrammetry are now frequently used in geomorphology to achieve greater precision and completeness in surveying natural environments than what was feasible a few years ago. Yet, scientific exploitation of these large and complex 3D data sets remains difficult and would benefit from automated classification procedures that could pre-process the raw point cloud data. Typical examples of applications are the separation of vegetation from ground or cliff outcrops, the distinction between fresh rock surfaces and rockfall, the classification of flat or rippled bed, and more generally the classification of 3D surfaces according to their morphology directly in the native point cloud data organization rather than after a sometime cumbersome meshing or gridding phase. Yet developing such classification procedures remains difficult because of the 3D nature of the data generated from ground based systems (as opposed to the 2.5D nature of aerial lidar data) and the heterogeneity and complexity of natural surfaces.

We present a new software suite (CANUPO) that can classify raw point clouds in 3D based on a new geometrical measure: the multi-scale dimensionality. This method exploits the multi-resolution characteristics high-resolution datasets covering scales ranging from a few centimeters to hundred of meters. The dimensionality characterizes the local 3D organization of the point cloud within spheres centered on the measured points and varies from being 1D (points set along a line), 2D (points forming a plane) to the full 3D volume. By varying the diameter of the sphere, we track how the local cloud geometry behaves across scales (typically ranging from 5 cm to 1 m). We present the technique and illustrate its efficiency on two examples : separating riparian vegetation from ground, and classifying a steep mountain stream as vegetation, rock, gravel or water surface. In these two cases, separating the vegetation from ground or other classes achieve accuracy larger than 98 %. Comparison with a single scale approach shows the superiority of the multi-scale analysis in enhancing class separability and spatial resolution. Given that full data resolution is rarely needed for final scientific analysis, we introduce the notion of core points which are a sub-sampled version of the original data on which calculations are done using full resolution. This way, scenes between ten and one hundred million points can be classified on a common laptop in a reasonable time. The technique is robust to missing data, shadow zones, spurious mixed-points and changes in point density within the scene. A probabilistic confidence in the classification result is given at each point, allowing the user to remove the points for which the classification is uncertain. The process can be both fully automated or fully customized by the user. We discuss and show why in complex natural 3D cases, this geometrical technique is currently superior to classification methods based on RGB imagery or laser reflected intensity.

The CANUPO software suite is available as Free/Libre software at the following address : http://nicolas.brodu.numerimoire.net/en/recherche/canupo/