Hierarchical Conditional Random Fields for the Classification of Airborne LiDAR Point Clouds in Urban Areas

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A two-layer hierarchical framework is used for the contextual classification of LiDAR point clouds. The supervised approach classifies points and segments, respectively, with two independent Conditional Random Fields (CRF). The methodology extends the work of [1] by applying *Voxel Cloud Connectivity Segmentation* [2] for the aggregation of points. The probabilistic outputs of the point-based CRF are able to affect the segmentation process. This improves the segmentation in each iteration step and reduces the amount of under-segmentation errors.

Features based on the intensity values and the geometry in a local point neighborhood are used. Fast Point Feature Histograms (FPFH) [3] are extracted in addition to [1]. The classification also considers contextual segment features. They model the distribution of object classes in a local neighborhood as well as the position and the orientation of each segment with respect to the closest road segment.

[1] Niemeyer, J., Rottensteiner, F., Soergel, U. & Heipke, C. (2016): Hierarchical Higher Order CRF for the Classification of Airborne LiDAR Point Clouds in Urban Areas. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XLI-B3, pp. 655-662. http://doi.org/10.5194/isprs-archives-XLI-B3-655-2016

[2] Papon, J., Abramov, A., Schoeler, M. & Worgotter, F. (2013): Voxel cloud connectivity segmentation - Supervoxels for point clouds. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 2027–2034. http://doi.org/10.1109/CVPR.2013.264

[3] Rusu, R. B., Holzbach, A., Blodow, N. & Beetz, M. (2009): Fast geometric point labeling using conditional random fields. In *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) 2009*, pp. 7–12. http://doi.org/10.1109/IROS.2009.5354763