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Exploring a Rough Sets-based framework for 3d image segmentation

We propose a modular approach to 3D point cloud segmentation that combines rough-set-inspired octree granulation with a Siamese neural network for pairwise granule comparison. The point cloud is recursively decomposed into an octree of spatial granules using data-dependent subdivision criteria--brightness range, point density, and color distribution--that formalize the notion of granule homogeneity from rough set theory. Neighboring leaf granules are then grouped into object segments either through region growing based on CIEDE2000 perceptual color similarity or through a learned pairwise classifier. The Siamese network processes pairs of granule point clouds, each represented by a 42 dimensional per-point feature vector comprising relative coordinates, RGB color, and a binary octree position encoding, and predicts whether the two granules belong to the same object. We evaluate 30 configurations of granulation and segmentation methods on the Stanford Large-Scale 3D Indoor Spaces (S3DIS) dataset. The combination of complex granulation (cascaded density and brightness criteria) with ML-based segmentation achieves the best IoU of 0.783, consistently outperforming all handcrafted segmentation approaches. The results demonstrate that rough-set-inspired spatial decomposition provides an interpretable and effective framework for structuring the 3D segmentation problem, while the learned pairwise comparison captures object boundaries more accurately than color-based heuristics.

Keywords: rough sets, 3d image segmentation, granule