

Abstract

This dissertation investigates the role of 3D feature representations in the semantic interpretation of point cloud data. The problem is studied from two complementary perspectives: the analysis of handcrafted geometric features and the design of hybrid deep learning approaches that integrate explicit geometric information into neural networks.

In the first part of the thesis, we evaluate 3D keypoint detectors, local feature descriptors, and their mutual combinations. The experiments are conducted on scenes with varying levels of occlusion and complexity. The results show that, although handcrafted features provide an interpretable description of local surface geometry, their performance is strongly dependent on the stability of keypoint detection. Occlusion and scene complexity reduce detector repeatability, which directly affects the quality of descriptor matching.

In the second part of the thesis, we focus on point cloud segmentation using deep learning and propose a hybrid architecture, HyGDANet, which extends the GDANet model by incorporating covariance-based geometric features, statistical neighbourhood characteristics, and direction-aware PointSIFT representations. We analyse the contribution of individual features, their combinations, and different fusion strategies.

The experimental results show that explicit geometric information can complement learned representations; however, its effectiveness depends on the integration strategy. Individual features provide moderate improvements, while their direct combination may introduce redundancy.

The thesis shows that local geometric information remains essential for understanding point clouds, but its role shifts from a primary representation to a complementary source of information within deep learning models. The results provide guidance for the design of hybrid architectures that combine explicit and learned feature representations.

Keywords: 3D point clouds, semantic segmentation, geometric feature representations, deep learning, hybrid architectures, PointSIFT