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Learning robust and efficient point cloud representations

By

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Point cloud processing is a crucial task in the field of computer vision and signal processing. With the recent increase in 3-D sensing technology, large-scale 3-D point clouds have become more and more available, providing a rich and comprehensive representation of the geometry of real-world objects and scenes. However, processing point clouds poses several challenges due to the irregular and unstructured nature of the data, the imperfect acquisition methods and heavy memory requirements.

Feature extraction is a key challenge for point cloud processing, involving the identification and description of important geometric and semantic features of a point cloud. Dealing with the irregular and unstructured nature of the data makes traditional processing techniques less effective or not applicable. Therefore, new techniques such as geometric deep learning methods and graph-based representations have been developed. Moreover, it has to be considered that all available techniques able to acquire point clouds insert non-negligible noise into the data, changing the global shape of the objects or scene. Therefore, it is particularly important design deep learning methods able to restore the original data and to extract robust features from noisy data. Notably, point clouds are characterized by a large amount of 3-D points with additional attribute information, such as colors or normals to the surface. The huge memory requirements are a critic aspect when it comes to processing this type of data, and there has been a growing interest and necessity in founding alternative memory-efficient data representation.

This thesis is focused on tackling and analyzing the critic aspects previously introduced and two main themes are investigated: i) learning robust graph convolutional features for point cloud processing in the presence of noise and ii) learning an efficient and compact representation for point cloud attributes.

Regarding the first topic, a novel graph convolutional neural network is investigated to learn meaningful features from raw noisy data. The focus of the research is to prove the suitability of the graph convolutional neural network for point cloud processing tasks, particularly in the presence of noisy data. Moreover, the results

demonstrate the power of the proposed network for a restoration task such as denoising.

Concerning the second topic, an efficient point cloud compression algorithm is investigated to tackle the problem of memory occupation. Compression algorithms can reduce the size of point cloud data, improving processing time and overall performance while reducing costs associated with handling large data sets. In this thesis, in particular the task of point cloud attribute compression is analyzed, and a novel signal compression algorithm based on neural implicit representations is proposed.

Overall, this thesis proposes novel deep learning-based techniques to address some of the main challenges in point cloud processing and to improve tasks such as denoising, surface normal estimation, and compression. The addressed problems are usually part of a processing pipeline. For instance, denoising is typically a pre-processing procedure used to improve downstream tasks, such classification, segmentation or compression. The research demonstrates the power of graph convolutional neural networks for point cloud processing tasks and provides a new approach for point cloud compression.