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Geometric Recognition and Analysis of 3D Data: Methods, Applications, and Future Research Directions

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Abstract

My research activity lies at the intersection of geometric computing, applied mathematics, and computer science, with a focus on the analysis, recognition, and fitting of geometric structures in 3D digital models. I develop robust methods for the identification of curves and surfaces in point clouds and meshes affected by noise, missing data, and acquisition imperfections. A core contribution of my work is the theoretical and computational extension of the Hough Transform to the 3D domain, enabling the automatic recognition of spatial curves and geometric primitives. These methods have been applied in several contexts, including cultural heritage, CAD, and urban. To test, evaluate, and compare the developed approaches with the literature, I created open datasets, software libraries, and international benchmarks freely available to the scientific community. In the last years, I have adapted these techniques for the reconstruction of large-scale urban environments, implementing efficient strategies for the semantic segmentation and geometric characterization of high-density point clouds representing entire cities. These methods identify building components such as façades, roofs, pavements, and structural elements through parametric fitting, and they integrate procedures for denoising, resampling, and reconstructing missing data. My future research ambitions follow three main directions. The first focuses on the evolution of innovative methodologies for the analysis and geometric modeling of the built environment, by contributing to the development of urban Digital Twins. The idea is to integrate 3D models, semantic information, and analytical and predictive tools to support the management, planning, and sustainable transformation of cities. The second concerns hybrid geometric modelling approaches that integrate mesh-based, parametric, and primitive-based representations into a unified model adaptable to different analytical and simulation needs. The third direction focuses on the interaction between geometry and artificial intelligence: on one side, through the generation of synthetic, controlled datasets for training neural networks, and on the other, through hybrid methods that combine deep learning with the Hough Transform for efficient and robust recognition of complex 3D shapes.

Keywords

Shape Analysis, Curve and Surface Recognition, Hough Transform, Primitive Fitting, Point Cloud Processing