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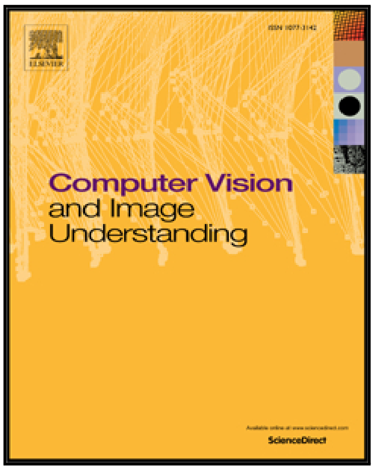

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Efficient Architectural Structural Element Decomposition

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Abstract

Decomposing 3D building models into architectural elements is an essential step in understanding their 3D structure. Although we focus on landmark buildings, our approach generalizes to arbitrary 3D objects. We formulate the decomposition as a multi-label optimization that identifies individual elements of a landmark. This allows our system to cope with noisy, incomplete, outlier-contaminated 3D point clouds. We detect four types of structural cues, namely dominant mirror symmetries, rotational symmetries, shape primitives, and polylines capturing free-form shapes of the landmark not explained by symmetry. Our novel method combine these cues enables modeling the variability present in complex 3D models, and robustly decomposing them into architectural structural elements. Our proposed architectural decomposition facilitates significant 3D model compression and shape-specific modeling.

Keywords: 3D city model, architecture, structure, element, landmark, decomposition, optimization

1. Introduction

Modeling our environment is a common strive in photogrammetry, computer vision and graphics. 3D modeling from imagery has been going through a great evolution over the past decades, maturing methods like incremental Structure-from-Motion (SfM) [1, 2, 3], Internet-scale point cloud reconstruction from imagery [4], high-accuracy detailed surface reconstructions via dense Multi-View Stereo (MVS) [5, 6], and ach ieved success in procedural modeling of facades [7, 8]. LiDAR is an alternative dominant technology to obtain point clouds of urban scenes [9].

In this work, we tackle the abstraction and understanding of 3D point clouds delivered by such state-of-the-art technologies. Planar priors [10, 11, 12, 13], or a Manhattan-world assumption [14] proved to be enough for many man-made structures. However, for a large mass of buildings, especially landmark architecture or general objects, a simple shape primitive abstraction will not suffice. Instead, we propose to decompose a 3D reconstruction by exploiting symmetries within the model. Such a decomposition is a first step towards understanding and compactly modeling the architectural elements of a landmark.

Our method is based on weak architectural priors that naturally hold for a majority of buildings, namely mirror symmetries, rotational symmetries and wall verticality. The method starts with a semi-dense 3D point cloud that may be contaminated by noise and gross outliers, and may be highly inhomogeneous. Structure-from-Motion (SfM) point clouds often suffer from such contamination. We show how to robustly detect *structural cues*, more precisely, axis directions of dominant mirror symmetries, the pivot of rotational symmetries, shape primitives, and free-form parts that are not explained by the symmetries. These cues provide a strong guidance for extracting dominant and semantically meaningful components of a model, such as a wall, a tower, an arch, etc., as illustrated in Figure 1. We refer to these components as *architectural structural elements* (ASE) throughout this work. We formulate the decomposition problem as an energy-driven, multi-label point cloud segmentation. Our contributions:

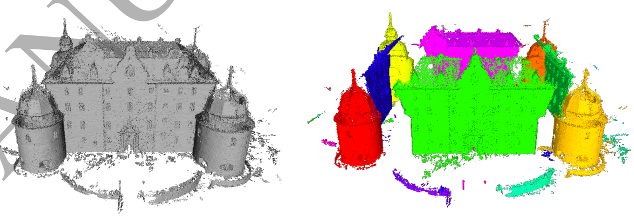

Figure 1: Our method segments a point cloud of a landmark building into coherent architectural structural elements, such as walls, towers based on structural cues. The noisy points that do not belong to any component get a random assignment.

- a model that combines symmetries and free-form polylines for decomposing a point cloud into ASEs,
- methods for detecting structural cues (dominant mirror symmetries and bodies of rotation, as well as residual free-form parts) in point clouds,
- a global energy formulation and optimization approach for partitioning a point cloud into meaningful structural components based on structural cues.

Our proposed abstraction paves the road to 3D model compression [15] or to shape-specific models [16, 17].

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