

# SYMMETRY AND STRUCTURE DETECTION FOR 3D GEOMETRY

NILOY J. MITRA

Shape acquisition, model building, and data representation constitute fundamental components of any geometric modeling tasks. We will begin with some of the basic concepts in this area along with brief expositions of a few specific algorithms and procedures. After a quick overview, we will study a specific problem in detail, specifically geometry processing for shape understanding. This will demonstrate the various challenges which are typical in most geometry processing tasks where we have to deal with approximate and imperfect data.

Self-similarity or symmetry is commonly observed in many natural and man-made objects. Recent research efforts have lead to robust symmetry detection algorithms for images [LoE06]. As we enter the age of easily accessible large collections of 3D data, such global understanding of the underlying structure of data becomes more relevant and useful. I will summarize recent contributions towards detecting and enhancing symmetries in 3D geometry [PSG<sup>+</sup>06, MGP07]. We will study in detail an algorithm for detecting partial and approximate symmetries in 3D shapes. The algorithm, motivated by classic techniques like Hough Transform and Geometric Hashing, works in a derived transform space where symmetry is better exposed, and hence easier to detect efficiently and robustly.

Being able to detect approximate symmetries, it is natural to ask how to make objects more symmetric by removing imperfections. We will discuss an algorithm which enhances approximate symmetries of a model while minimally altering its shape [MGP07]. Symmetrizing deformations are formulated as an optimization process that couples the spatial domain with a transformation configuration space, where symmetries can be expressed more naturally and compactly as parametrized pointpair mappings. We derive closed-form solution for the optimal symmetry transformations, given a set of corresponding sample pairs. The resulting optimal displacement vectors are used to drive a constrained deformation model that pulls the shape towards symmetry.

Finally we will study a computational framework for discovering regular or repeated geometric structures in 3D shapes [PMW<sup>+</sup>08]. We describe and classify possible regular structures and present an effective algorithm for detecting such repeated geometric patterns in point- or mesh-based models. The method assumes no prior knowledge of the geometry or spatial location of the individual elements that define the pattern. Structure discovery is made possible by a careful analysis of pairwise similarity transformations that reveals prominent lattice structures in a suitable model of transformation space. We will study an optimization method for detecting such uniform grids specifically designed to deal with outliers and missing elements. This yields a robust algorithm that successfully discovers complex regular structures amidst clutter, noise, and missing geometry.

Applications include model compression, segmentation, semantic model editing [MP08], automatic registration, example based model completion [PMG<sup>+</sup>05].

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