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Accurately Detecting Symmetries of 3D Shapes

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Goals and Motivations
Many shapes and geometrical models exhibit symmetries. These symmetries are sometimes explicitly represented in the model. However, symmetry information is often lost in automatic translations between file formats.

Using symmetries, one can, for example, manipulate models through coherent re-meshing or intelligent mesh editing programs.

We present two algorithms that automatically retrieve symmetries in a 3D model through the use of an intermediate set of functions:

The Generalized Even Moments

Overview

A. Symmetries of single shapes: Direct Algorithm

Computation of the Generalized Even Moments:

\[ M^e(w) = \int |s \times w|^2 \, ds \]

Deterministic extraction of moment symmetries

We prove that any symmetry of a shape is also a symmetry of all its moment functions. The presented algorithm relies on this property and is divided in three main steps:

- **Computation of the Generalized Even Moments:** This computation is made easy by the fact that these functions decompose onto a finite number of spherical harmonics.
- **Deterministic extraction of moment symmetries:** Potential axes of symmetries are computed analytically and symmetry parameters are found by using spherical harmonic coefficients.
- **Candidate filtering:** Candidate symmetries have to be checked on the shape. This is done by computing a symmetry measure.

B. Symmetries of Assembled objects: Constructive algorithm

By considering an object as made of several sub-parts, we present an algorithm that pushes the accuracy issues down to a smaller scale in the object.

Decomposition into tiles: A tile is defined as a maximal set of edge-connected polygons.

Tile Registration: We use a new shape descriptor, based on the various moment functions to easily detect congruent tiles. We use these informations to attach a local frame to each tile.

Tile Symmetries: We use the direct algorithm (described above) on each tile independently.

Shape Symmetries: We explore all one-to-one mappings between congruent tiles and progressively restrict allowable symmetries of the whole shape.

Results and Applications
Our algorithm finds symmetries in fairly complex models. Regarding accuracy, both algorithms compute the axes of the symmetries with a maximum error of 10^-4 radians, independently of shape complexity.

Other potential applications include:
- Model compression
- Consistent texture-mapping
- Automatic instantiation

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