Deformable Voxel Grids

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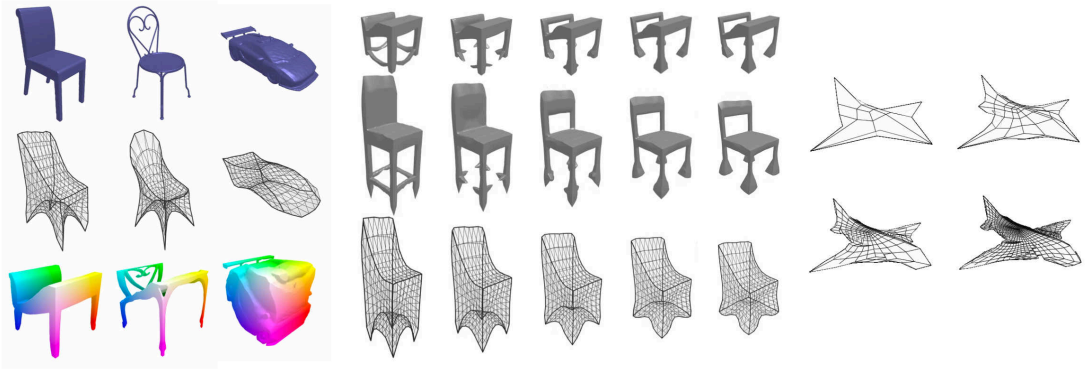
We introduce Deformable Voxel Grids (DVGs), an adaptation of Active Volumes for semi-automatic shape preprocessing. Intuitively, they deform the embedding space to a given shape in order to facilitate further shape processing and analysis, by means of shape-DVG registration. A DVG is parameterized like a Topological Active Volume [3], which is a volumetric extension of active contours [1, 2]. It is a lattice V on the unit cube, evolving with an energy designed to smoothly embrace shape S: $\mathcal{E}(V) = \lambda_e \mathcal{E}_{elastic}(V) + \lambda_b \mathcal{E}_{bending}(V) + \lambda_s \mathcal{E}_{S \subset V}(V)$. The last term, $\mathcal{E}_{S \subset V}$, penalizing the non-inclusion of S in V, acts as a stopping barrier against the contraction induced by $\mathcal{E}_{elastic}$. To compute it, we approximate V with a dense ball covering, because each cell is hexahedral.



Once optimized, two things follow: (1) expressing S in coordinates $(u, v, w) \in [0, 1]^3$ taken from the same parameterization than $V(u, v, w)$; (2) attributing scalar values to the cells of V, corresponding to the volume occupancy of S within them. We call these operations *registration* and *cubification*. Indeed, (1) allows to deform S by moving the control points of V, while (2) gives a "cubic" representation of the topology of S (see accompanying image). DVGs provide a proxy for various applications, some of which are illustrated above:

Similarity search: Relying solely on V, which approximates the outer surface of S, gives a topological-invariant shape descriptor which can be used to retrieve models similar to a given query model.

Semantical editing: Learning deformation modes of V (e.g. with a PCA) on a dataset, to induce a similar deformation on DVG-registered shapes.

Topology transfer: Projecting a registered shape into the DVG of a different shape.

Basic correspondences: Cubified shapes tend to have similar parts in similar locations (color-coded above), which suggests a potential for estimating shape correspondences, using a naive closest-point matching.

Morphing: For a pair of registered shapes, interpolating separately on the V lattice and the cubified shapes (separating "form" and "content"). See above the three rows of interpolations (result in the center).

Progressive approximation with quadrilaterals: Surfaces given as triangle meshes can be approximated by quadrilateral meshes, by voxelizing the cubified shapes and reprojecting to the DVG.

References

[1] M. Kass et al. Snakes: Active contour models. *International Journal of Computer Vision*, 1(4):321-331, 1988.

[2] Laurent D. Cohen. On active contour models and balloons. *CVGIP: Image Understanding*, 53(2):211-218, 1991.

[3] N. Barreira et al. Topological Active Volumes. *Computer Analysis of Images and Patterns*, 337-344, 2003.