Visual Hull from Imprecise Polyhedral Scene

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Topics to Address

- **Background**
  - Visual Hull Concepts
  - Solid Domain
    - Definition
    - Basic Elements
- **Partial Visual Hull**
  - Partial Quadratic Surface
  - Algorithm
Visual Hull Concept

- The best geometric shape of an object $O$ we can obtain from its silhouettes
- Better than convex hull

$$O \subseteq VH(O) \subseteq CH(O)$$

- Visual (silhouette) cones
- 3D Visual Number
  - Number of edges (faces) of the visual cones
  - The visual hull contains all the points with visual number 0
Visual Active Surfaces

- Bounded by 2 kinds of surfaces, *i.e.* VE and EEE surfaces
  - Planar surfaces (from a vertex and an edge)
  - Quadratic surfaces (from 3 edges)
**Classical Algorithm**

**Input** : A polyhedral scene defined by classical vertices

**Output** : The visual hull of the scene

- Find all active surfaces;
  - Planar
  - Quadratic
- Determine the cells interwoven by active surfaces;
- Label each cell with visual number;
- Merge cells with visual number 0.
Solid Domain \((\mathbf{S}X, \sqsubseteq)\)

- A partial geometric object \(O\)
  - Interior \(O_I\)
  - Exterior \(O_E\)
  - Partial Boundary \(\partial_P O\)
- A partial order “\(\sqsubseteq\)”: \((A_I, A_E) \sqsubseteq (B_I, B_E)\)
  \[\uparrow\]
  \[A_I \subseteq B_I \text{ and } A_E \subseteq B_E\]
- A basis for partial polyhedra in \(\mathbf{S}\mathbb{R}^3\) is the set of partial polyhedra with rational vertices.
Partial Elements

- Partial Point
- Partial Line
  - Partial Lines Segment
- Partial Plane
  - Partial Face
Quadratic Surface from 3 Skewed Lines

- Hyperbolic paraboloid
  - 2 families of mutually skewed lines (doubly ruled)
  - 2 lines from different families are coplanar
- 3 general skewed lines determine a hyperbolic paraboloid
A partial quadratic surface
\[ PQ = \bigcup \{ l | l \cap PL_i \neq \emptyset \} \]

A partial quadratic surface can be constructed from

- 3 pairs of partial points
- 3 partial lines (segments) (\(PL\)'s)
- Boundary surfaces of \(PQ_i\) and \(PQ_E\) are from boundary lines of \(PL\)'s
Conservative Partial Quadratics Surfaces

- Find the positive and negative lines for each Partial edges.
- Calculate the 6 quadratic surface patches which seamlessly form the boundaries of the conservative partial quadratic surface:
  \[ PEEE^+_c|_{l_{i+1}^p} = Q(l_i^p, l_{i+1}^p, l_{i+2}^n)|_{l_{i+1}^p} \]
  \[ PEEE^-_c|_{l_{i+1}^n} = Q(l_i^n, l_{i+1}^n, l_{i+2}^p)|_{l_{i+1}^n} \]
- Assemble the patches and determine the orientation.
Given a partial polyhedral scene, a point $p$ may have multiple visual numbers:

$$PVN(p, PS) = \bigcup \{ VN(p, S) | S \text{ is any possible classical scene} \}$$

The interior and exterior of the partial visual hull can be therefore defined.

$$PVH_I(PS) = \bigcup \{ p | \max PVN(p, PS) = 0 \}$$
$$PVH_E(PS) = \bigcup \{ p | \min PVN(p, PS) > 0 \}$$

In practise we use a conservative partial visual number

$$CPVH_I(PS) = \bigcup \{ p | \max VN(p, PS_I) = 0 \} \subseteq PVH_I(PS)$$
$$CPVH_E(PS) = \bigcup \{ p | \min VN(p, PS_E) = 0 \} \subseteq PVH_E(PS)$$
Partial Visual Hull

- Construct a partial polyhedral scene $PSN$.
- Compute all potential visual event surfaces.
- Partition the whole $\mathbb{R}^3$ space into disjoint cells;
Calculate the upper and lower bounds of the partial visual number set for each cell;

Merge all cells $c$ with $\max PVN(c) = 0$ to the interior.

Merge all cells $c$ with $\min PVN(c) > 0$ to the exterior.