Parameterization of polylines in unorganized cross-sections and open surface reconstruction

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Typical computer-assisted design software reconstructs 3D surfaces by interpolating polylines hand-picked in unorganized cross-sections (not necessarily parallel or orthogonal). Modern approaches mainly consider reconstructing closed surfaces [1]. However, open geological surfaces are frequently found in oil & gas exploration. Some point cloud interpolation methods can reconstruct open surfaces [2]. The authors indeed parameterize points of space $\mathbf{x}_i \in \mathbb{R}^3$ into a convex planar domain where each associated point $\mathbf{u}_i \in \mathbb{R}^2$ is made the "barycenter" of its 3D geometrical neighbors $\mathbf{x}_j \in N_i^G$ as in equation 1. Interpolation is then performed in parameter space, and the resulting surface transformed back in $\mathbb{R}^3$. $\lambda_{i,j}$ are built using the inverse distance in $\mathbb{R}^3$ [2].

$$\mathbf{u}_i = \sum_{j \in N_i^G} \lambda_{i,j}^G \cdot \mathbf{u}_j \ , \quad \lambda_{i,j} > 0 \ , \quad \sum_{j \in N_i^G} \lambda_{i,j} = 1 \tag{1}$$

Compared to point clouds, polylines are sparse and irregularly distributed: using geometrical neighbors requires a large distance to define N_i^G and handles closed polylines well, but contracts polylines in parameter space. However by locally seeing the polylines as a connected graph, any polyline vertex has a set of topological neighbors that we note N_i^T. Replacing N_i^G by N_i^T leads to a regular distribution of points in parameter space, but closed polylines end up aligned and degenerate. In order to balance this, we propose to use a weighted sum of both neighborhoods to benefit from their respective advantages (see equation 2).

$$\mathbf{u}_i = \alpha \sum_{j \in N_i^G} \lambda_{i,j}^G \cdot \mathbf{u}_j + (1-\alpha) \sum_{j \in N_i^T} \lambda_{i,j}^T \cdot \mathbf{u}_j \tag{2}$$

Instead of a global α value, an even better parameterization can be obtained by computing an optimal α_i for each $\mathbf{u}_i$ that optimizes the distribution of the $\mathbf{u}_i$ similarly to the $\mathbf{x}_i$ (equation 3).

$$\alpha_i = \arg\min_{\alpha} || \ \mathbf{x}_i - \alpha \sum_{j \in N_i^G} \lambda_{i,j}^G \cdot \mathbf{x}_j - (1-\alpha) \sum_{j \in N_i^T} \lambda_{i,j}^T \cdot \mathbf{x}_j \ ||^2 \tag{3}$$

Our approach supports sparser input data and reconstructs open surfaces from a set of open and closed polylines (see figure 1). Optimization of neighborhood N_i and weights $\lambda_{i,j}$ is ongoing, with promising results.

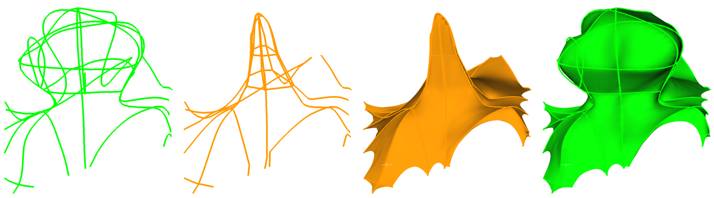

Figure 1: Left to right: Polylines representing a salt dome. (u, v, z) parameterized polylines with 2D parameter coordinates. Triangulation in (u, v, z). Transformation back to (x, y, z)

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References

[1] M. Zou and M. Holloway and N. Carr and J. Tao. Topology-constrained surface reconstruction from cross-sections. *ACM Transactions on Graphics*, 34(4):128:1–128:10, 2015

[2] M. S. Floater and M. Reimers. Meshless parameterization and surface reconstruction. *Computer Aider Geometric Design*, 18(2):77–92, 2001