Feature curve preservation and resampling in 3D point clouds

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Point clouds are widely used in applications such as manufacturing, cultural heritage preservation, CAD modeling, and urban mapping. However, acquired raw point clouds are usually affected by noise, outliers, and non-uniform sampling. These problems can hinder reliable surface reconstruction and, in particular, the accurate identification and preservation of structural and feature curves, such as edges and intersection lines between geometric primitives.

In this work, we present a unified mathematical framework for detecting, refining, and preserving feature curves in 3D point clouds through the combination of geometric primitive recognition with parametric curve modeling. Many manufactured objects can be effectively described using simple geometric primitives such as planes, cylinders, spheres, and cones. In such cases, feature curves can be analytically computed as the exact intersections between adjacent primitives. To achieve this, we first recognize each single primitive that composes the object using the Hough transform technique [1], and then we derive explicit and compact formulations for the intersection curves using a matrix-based representation, providing a unified and continuous description of these curves. For the recognition of geometric primitives, we exploit the method described in [2], which proposes a parameter-driven space discretization able to optimize the search for the optimal solution.

When feature curves cannot be reliably described as exact primitive intersections, due to free-form geometry, we adopt a piecewise parametric representation, reconstructing spatial curvilinear profiles as piecewise polynomial curves [3]. To detect these curves robustly, we apply the Hough transform, which allows for reliable identification of curve segments even in the presence of noise, outliers, and incomplete data. The resulting representation consists of curves that are G^1-continuous, with potential C^0 junctions occurring at corners or cusps.

We utilize both exact and approximate curve representations to guide a resampling and simplification process. This ensures that the feature curves are consistently preserved in line with the overall point density [4]. Finally, we produce different geometric representations at various sampling levels that explicitly incorporate both linear and curved feature elements. This supports subsequent geometric analysis, numerical processing, and surface reconstruction.

Joint work with: Silvia Biasotti, Bianca Falcidieno.

References

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