Subset-Constrained Simplification of Trajectory Streams

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February 13, 2026

Abstract

We study the problem of simplifying trajectory streams under the Fréchet distance with subset constraints. Given a trajectory stream τ of d-dimensional vertices arriving online, for any $\delta > 0$, we compute a simplified curve σ such that $d_F(\sigma, \tau) = O(\delta\sqrt{d})$ with constant-factor approximation on output size and $O(1)$ working storage.

We present a hypercube-based streaming algorithm to maintain a feasible region for vertex selection in high dimensions. Using a ridge-to-ridge method, we construct feasible regions with only $O(d^2)$ hyperplanes, avoiding exponential cost from the curse of dimensionality. For each $(d-2)$-dimensional ridge r_f^i of the previous facet f, we select the optimal matching ridge r_j^i from the current hypercube, where the ridge pair (r_f^i, r_j^i) defines a bounding hyperplane of the feasible region.

We prove that any bounding hyperplane of the feasible region must be tangent to both the facet and current hypercube while separating them, and show that our construction identifies exactly these hyperplanes through the ridge-to-ridge selection strategy.

To eliminate the $\sqrt{d}$ factor, we explore a dimension reduction strategy via random linear projection. By selectively projecting vertices, we aim to achieve dimension-independent approximation guarantees.

Keywords: Fréchet distance; Streaming algorithms; Trajectory simplification; Approximation algorithms; Dimension reduction