Tropical Cyclone Event Sequence Similarity Search via Dimensionality Reduction and Metric Learning

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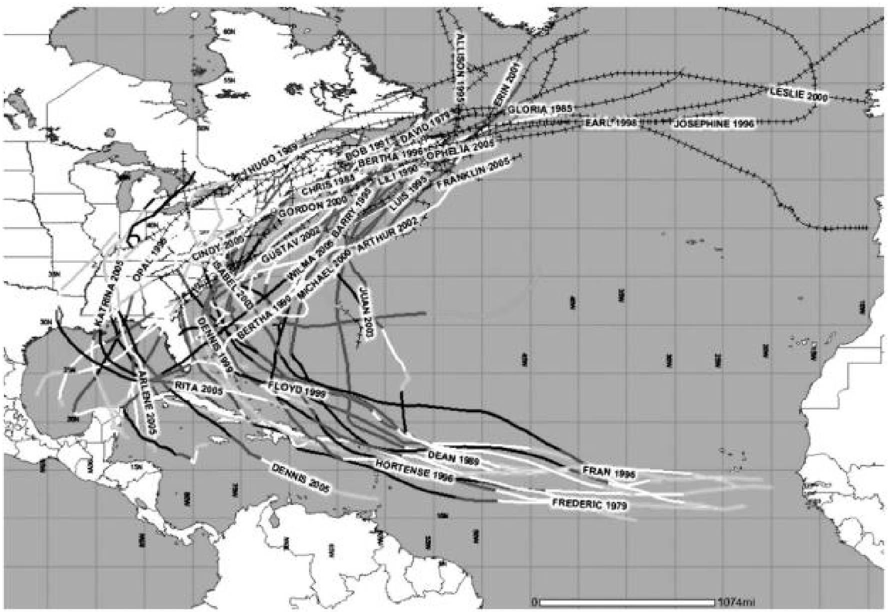
Outline

- Brief Motivation
- Methodology: Intuitions
- Some Experimental Results
- Open Problems

Brief Motivation (I)

Examples of “Conventional” similarity and objective query of interest to scientists or meteorologists:

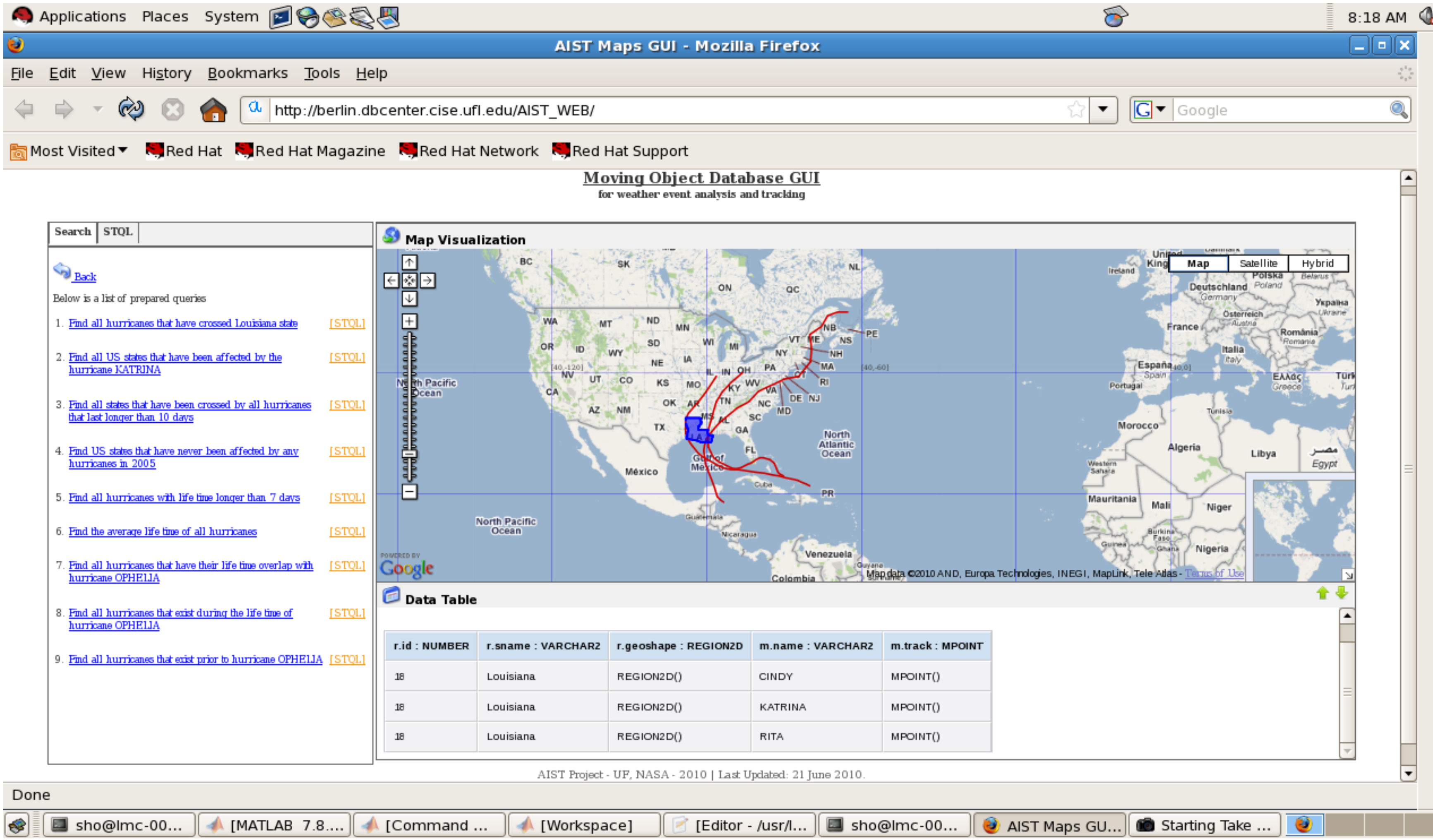
- Track Similarity: Find all hurricanes that crossed region ***A***, ***B***, ***C***, …
- Intensity Similarity: Find all hurricanes that had intensity at least *D* km/h.
- Origin Similarity: Find all hurricanes that evolved from region ***E***.



“Find all hurricanes that crossed Windsor, Ontario, and St. John's, Newfoundland from 1979 to 2005.”

Shawn M. Milrad, Eyad H. Atallah, and John R. Gyakum, ``Dynamical and Precipitation Structures of Poleward-Moving Tropical Cyclones in Eastern Canada, 1979--2005'', Monthly Weather Review, vol. 137, pp. 836-851, Mar. 2009

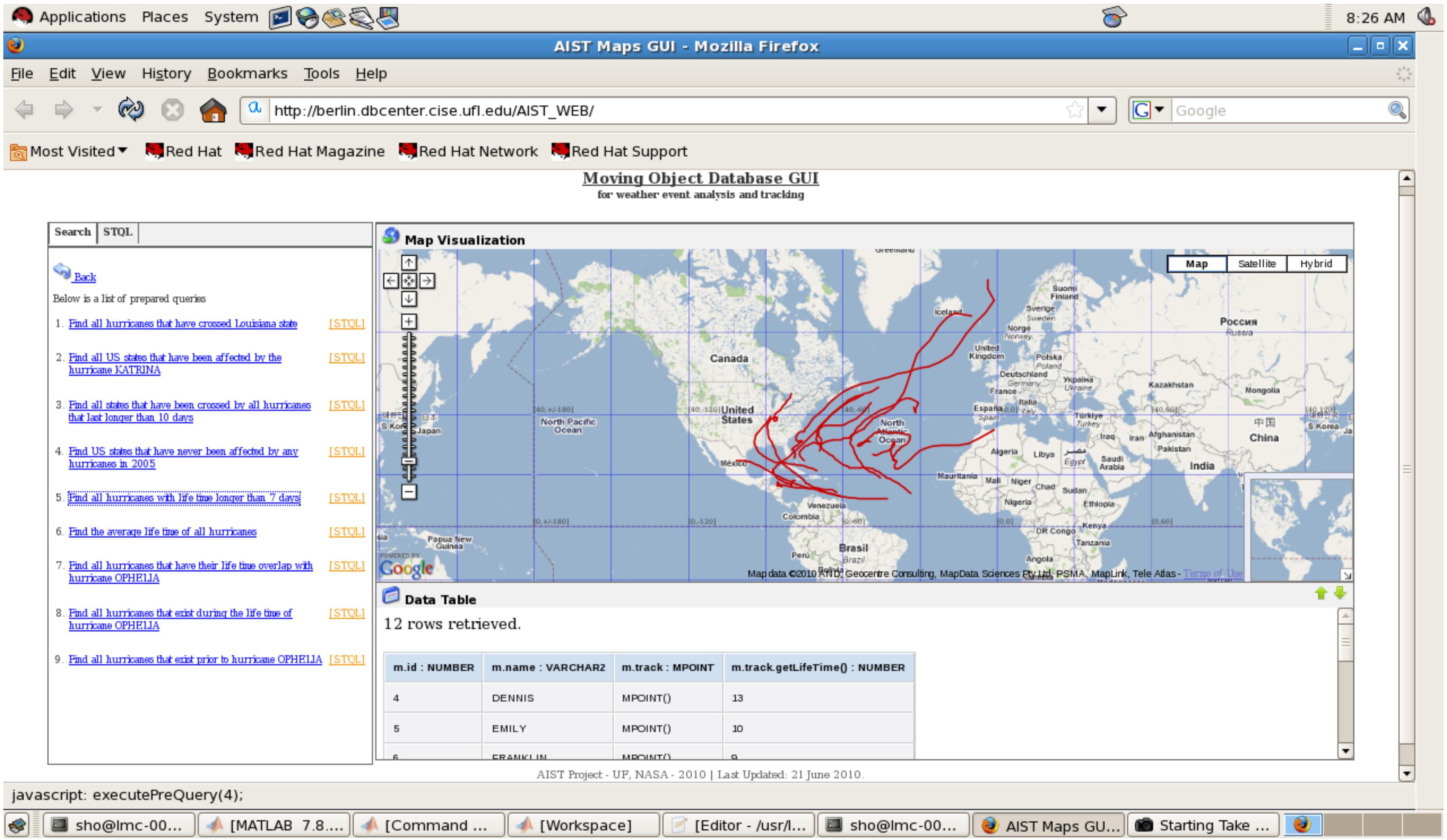
Brief Motivation (II)



Find all hurricanes that have crossed Louisiana state in 2005.

M. Schneider, S.-S. Ho, T. Chen, A. Khan, G Viswanathan, W. Tang, and W. T. Liu, Moving Objects Database Technology for Ad-Hoc Querying and Satellite Data Retrieval of Dynamic Atmospheric Events, 2010 Earth Science Technology Forum, June 22-24, Arlington, VA, 2010.

Brief Motivation (III)



Find all hurricanes that have life-time longer than 7 days in 2005

Brief Motivation (IV)

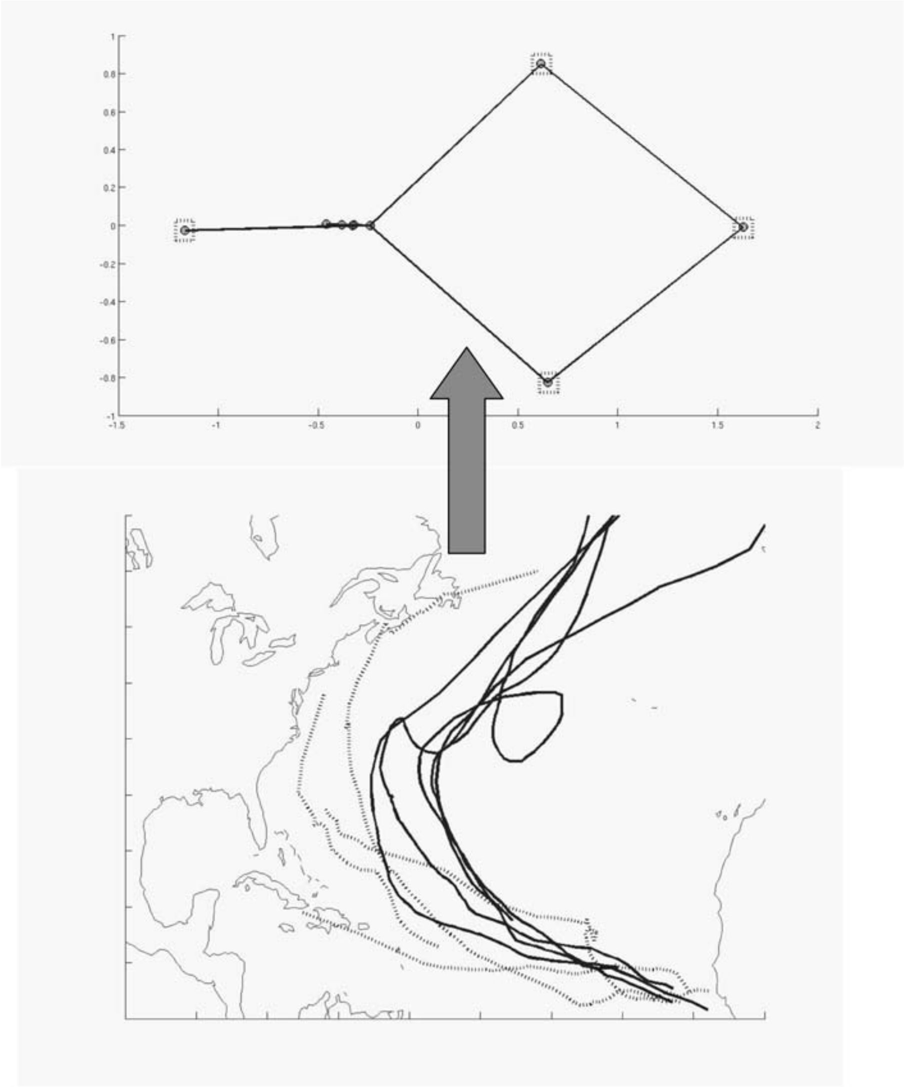
Query with instance-level constraints/user-defined "subjective" data constraints

Find all hurricanes that are *similar* to hurricane A, B, C, … and *dissimilar* to hurricane a, b, c, …

General Data Assumptions:

Multidimensional (Spatial, Temporal, Features/Attributes)
Arbitrary Length Sequences

Methodology (I)



Standard Data Mining Techniques Used:

- **Similarity Metric: Longest Common Subsequence (LCSS) – [Vlachos et al., ICDE, 2002] - generalize to multidimensional sequences**

$$S1(A,B,\delta,E) = \frac{LCSS_{\delta,E}(A,B)}{\min(|A|,|B|)}$$

$$LCSS_{\delta,E}(A,B) = \begin{cases} 0 : & \text{if } |A| = 0 \text{ or } |B| = 0 \\ 1 + LCSS_{\delta,E}(Head(A), Head(B)) : & c_k > 0, \forall c_k, \ |t_i - t_j| < \delta \text{ is satisfied} \\ \max(LCSS_{\delta,E}(Head(A), B), LCSS_{\delta,E}(A, Head(B))) : & \text{otherwise} \end{cases}$$

$$\begin{pmatrix} c_1 \\ \vdots \\ c_m \end{pmatrix} = \begin{pmatrix} \epsilon_1 - |a_{1,t_i} - b_{1,t_j}| \\ \vdots \\ \epsilon_m - |a_{m,t_i} - b_{m,t_j}| \end{pmatrix}$$

- **Dimensionality Reduction: Isometric Feature Mapping (ISOMAP) – [Tenenbaum et al, Science, 2000)**

- **Metrics Learning: [Xing et al, NIPS, 2002]**

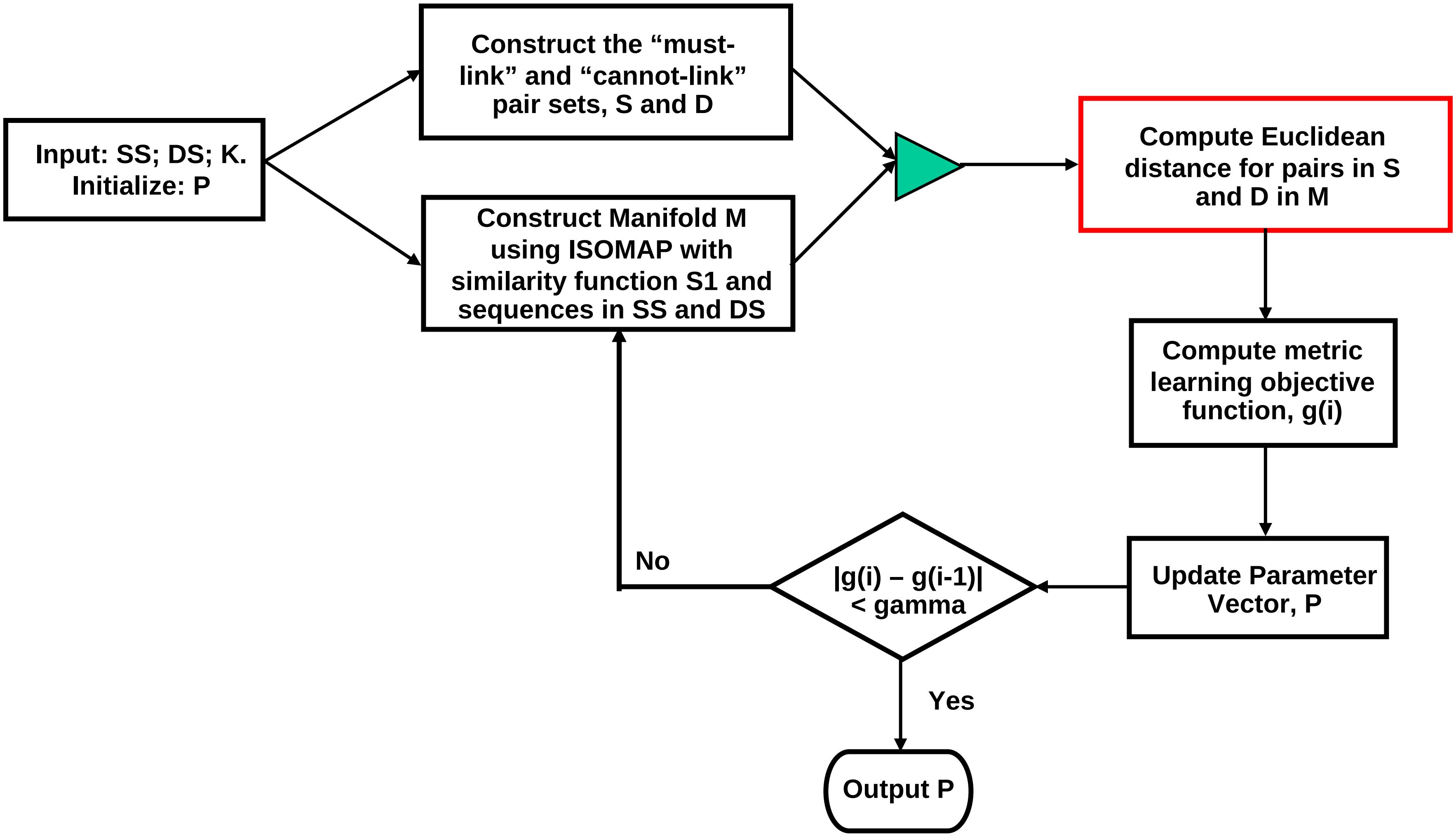
$$\min_{E,\delta} \quad \sum_{(x_i,x_j)\in S} ||f_{S1}(x_i) - f_{S1}(x_j)||^2$$

$$\text{such that} \quad \sum_{(x_i,x_j)\in D} ||f_{S1}(x_i) - f_{S1}(x_j)| \geq 1$$

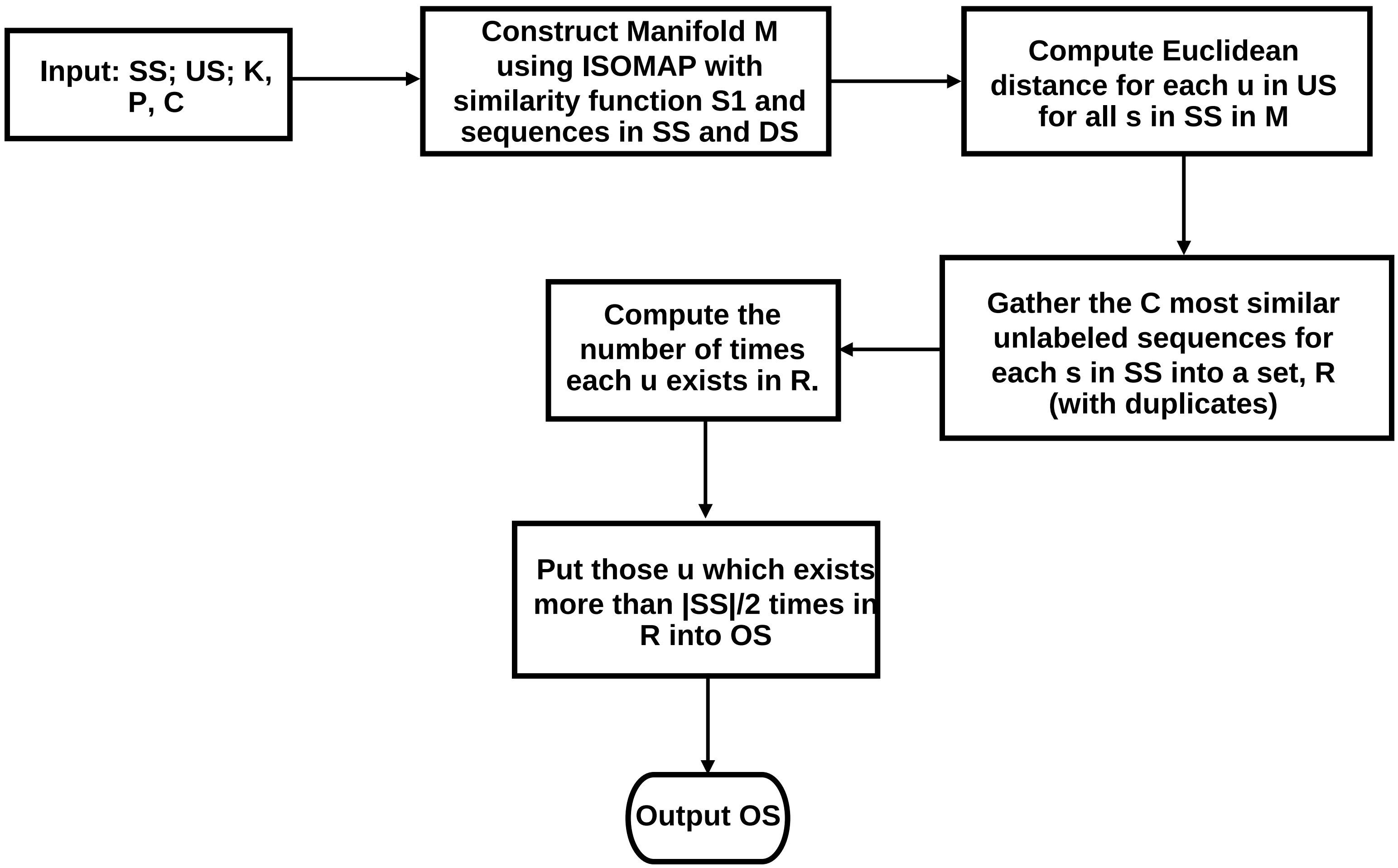
$$\text{and } P > 0 \qquad \text{where } P = (\epsilon_1, \epsilon_2, \ldots, \epsilon_m, \delta) \in (R^+)^m \times Z^+.$$

- **Similarity Search: Voting Approach**

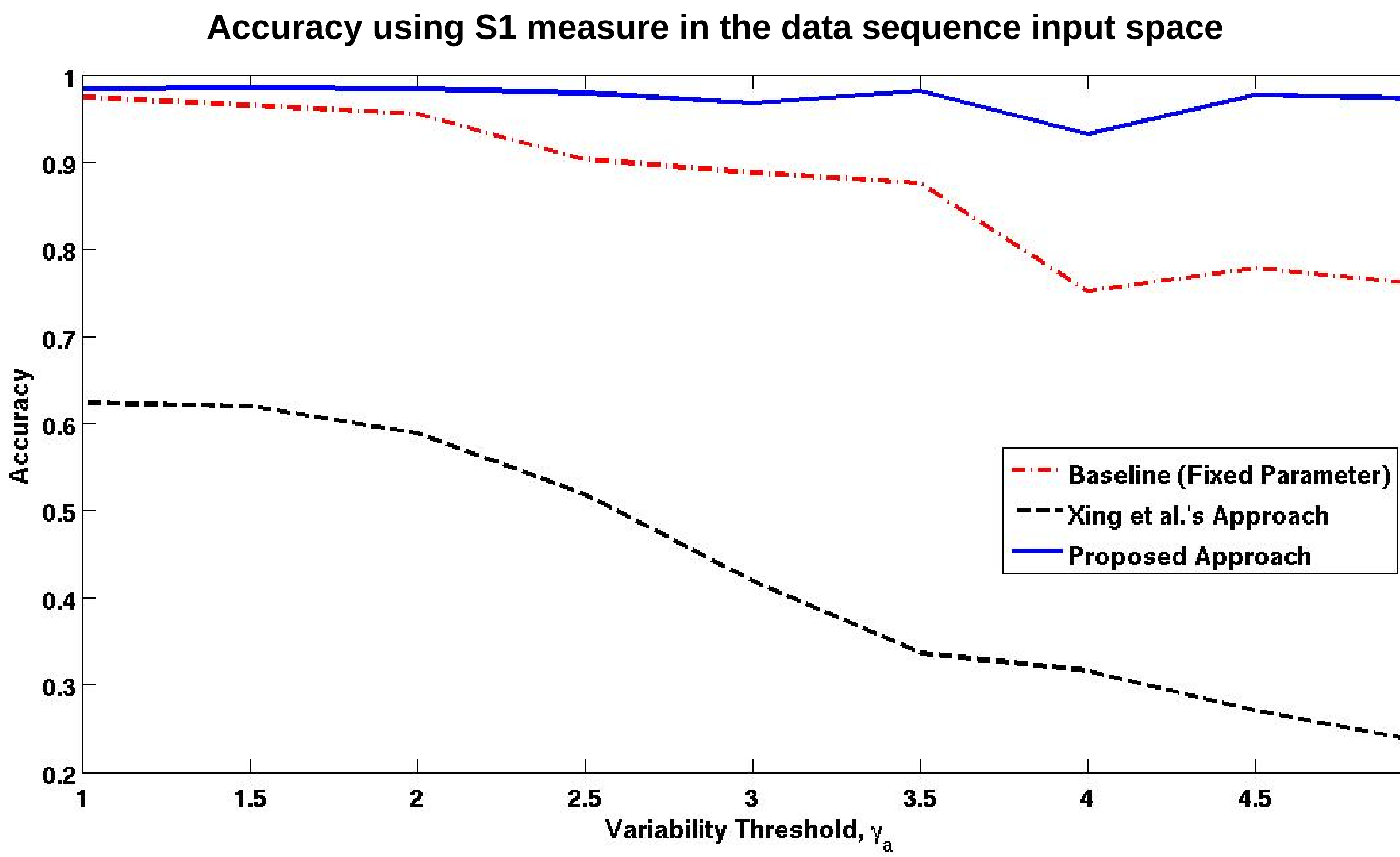
Methodology (III) – Learning LCSS Parameter P



Methodology (IV) – Similarity Search on Unlabeled Sequences U'

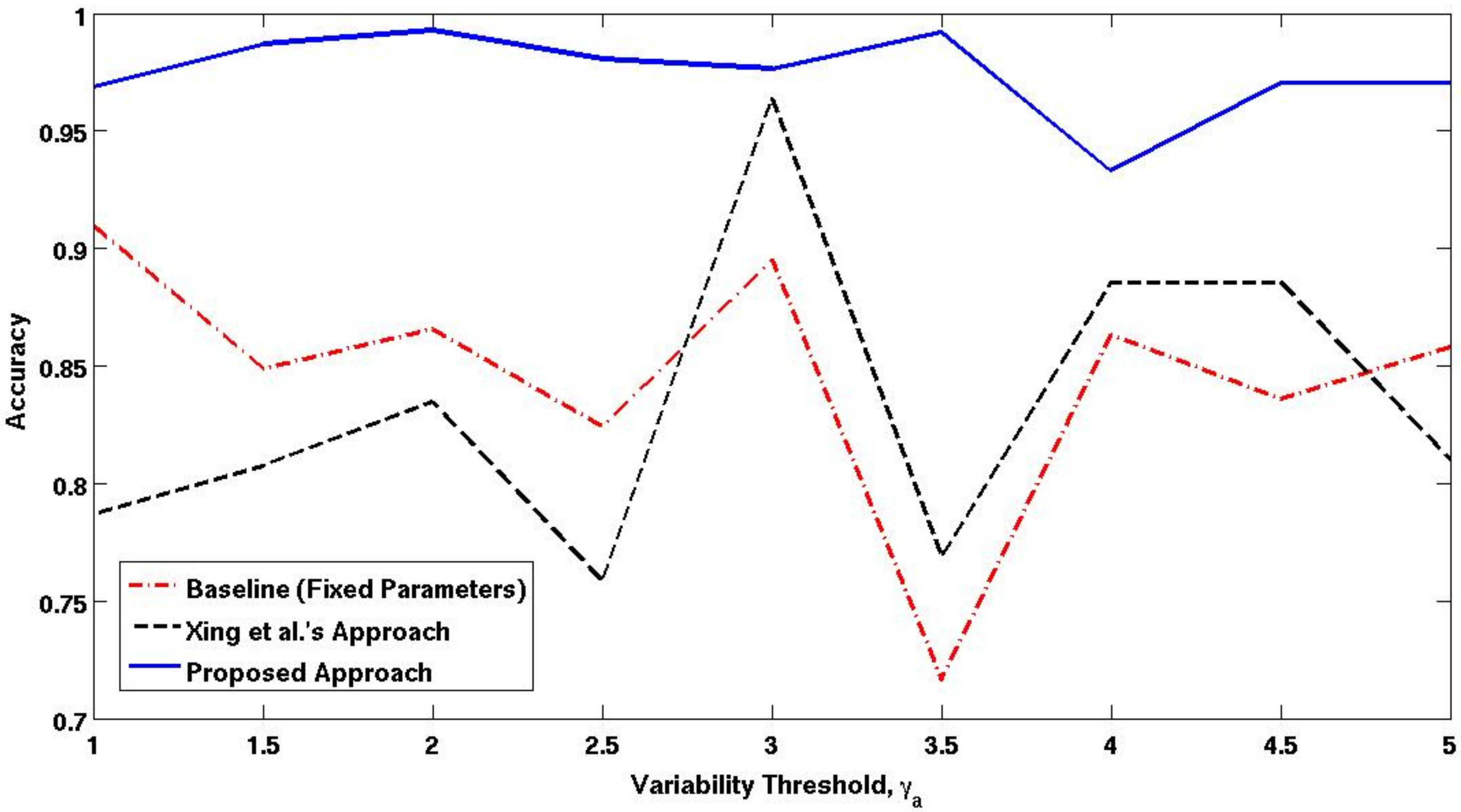


Experimental Results (I) – Learning P

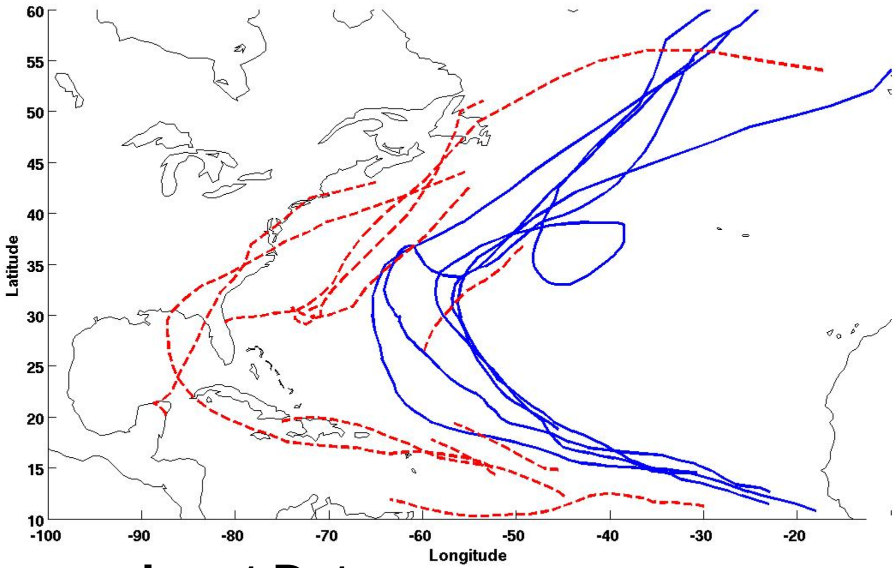


Experimental Results (II) – Learning P

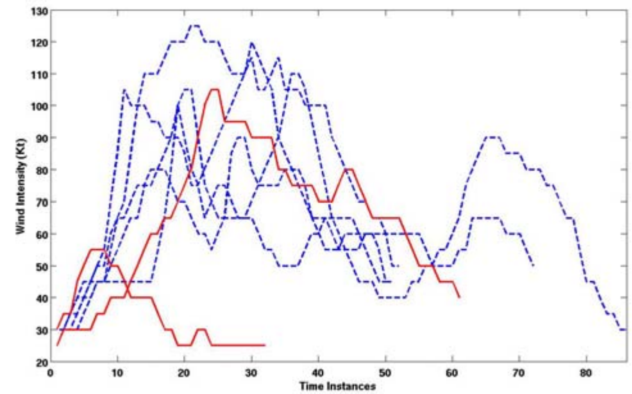
Accuracy using Euclidean distance in the low dimensional manifold

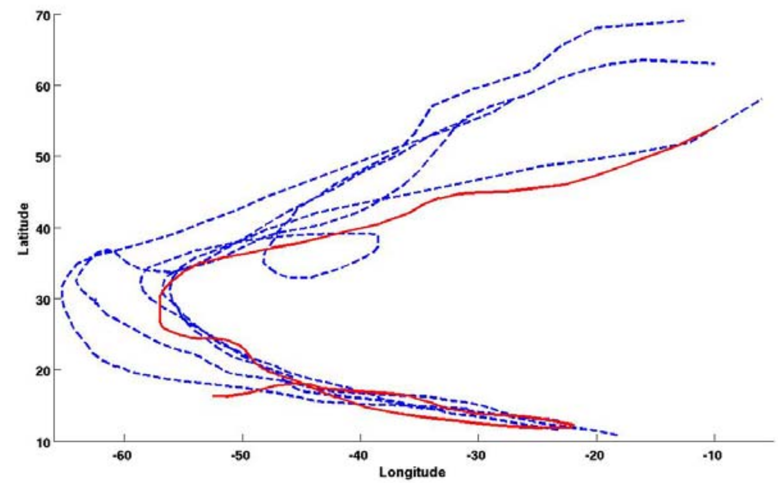


Experimental Results (III) – Similarity Search



Input Data





Output Result (Red)

Open Problems

- Theoretical justification for the setting and data assumptions.
- Which is the best similarity metric, dimensionality reduction approach, and metric learning approach for the framework?
- Local/partial sequence similarity search
- Other Applications …

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