Understanding Trajectory Behavior: A Motion Pattern Approach

Mahdi M. Kalayeh[1], Stephen Mussman[2], Alla Petrakova[1], Mubarak Shah[1]

[1]University of Central Florida [2]Purdue University

1. Problem

- **Objective**
  - Mining motion behaviors in trajectory data
  - *Trajectory* of length *L* is a sequence of points (t_i, x_i, y_i) where (x_i, y_i) denotes the observed location at time t_i and $i = 1, 2, \dots, L$.
- **Applications**
  - Urban planning, transportation management, GIS, animal migration tracking, anomaly detection, air traffic control and others.

2. Proposed Method

- Input trajectories.

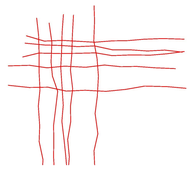


Figure 1

- Construct Pseudo-Optical Flow from trajectories:

$$X_i^j = (x_i^j, y_i^j, x_{i+1}^j - x_i^j, y_{i+1}^j - y_i^j) = (x_i^j, y_i^j, u_i^j, v_i^j)$$

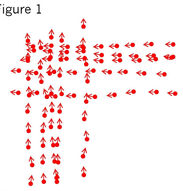


Figure 2

- 1st level clustering: cluster pseudo-optical flow with k-means in (x,y) subspace.

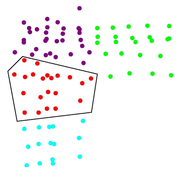


Figure 3

- 2nd level clustering: For each 1st level cluster, group pseudo-optical flow with k-means in (x,y,u,v).

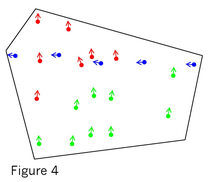


Figure 4

- Motion Components: For each 2nd level cluster, form a component by averaging the constituent pseudo-optical flows.

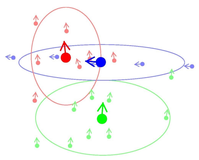


Figure 5

3. Reachability between Motion Components

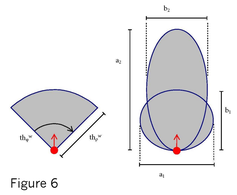


Figure 6

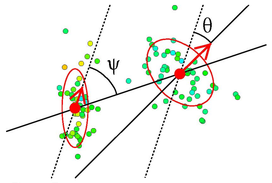


Figure 7

- *Double-Ellipse*: Motion component B is reachable from motion component A if B falls in the double-ellipse of A and both $|\theta| < th_\theta$ and $|\theta - \alpha\psi| < th_{\psi\theta}$.
- *Wedge*: B is reachable from A if B falls in wedge of A and $|\theta| < th_\theta^w$.
- Unblocking components that are unreachable or cannot reach others.

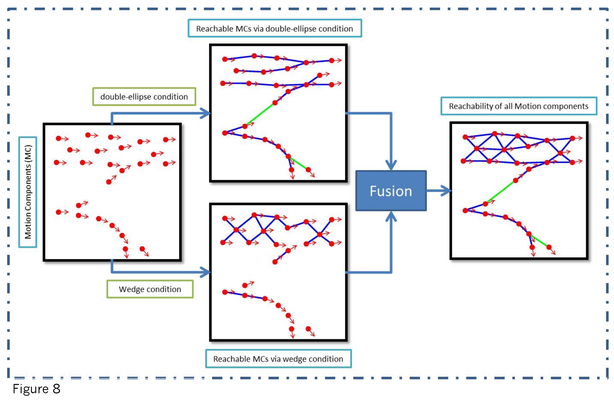


Figure 8

- *Path Reachable*: One motion component is path reachable from another if there is a chain of motion components between them where for each link, the second motion component is reachable from the first.
- *Signature*: For a motion component C, the signature of C is the set of motion components that are path reachable from C or from which C is path reachable.

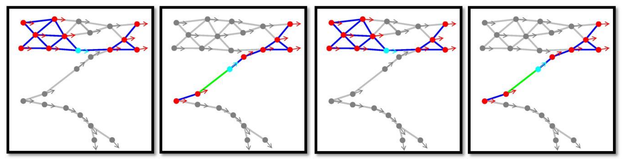


Figure 9

- *Weighted Jaccard Distance*: The motion patterns are formed by agglomerative clustering with respect to the weighted Jaccard Distance.

$$WJD_n^m = \frac{\sum_{i \in Sig(MC_m) \cap Sig(MC_n)} wgt_i}{\sum_{i \in Sig(MC_m) \cup Sig(MC_n)} wgt_i} \qquad wgt_i = \left(w_0 + \sum_{j=1}^{K} e^{\left(-\frac{dist(MC_i, MC_j)^2}{2\sigma^2} \right)} \right)^{-1}$$

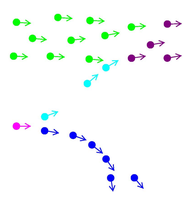


Figure 10

4. Experimental Results

Intersection Dataset[1]:
Dataset containing 1500 trajectories gathered by tracking vehicles at a traffic intersection.

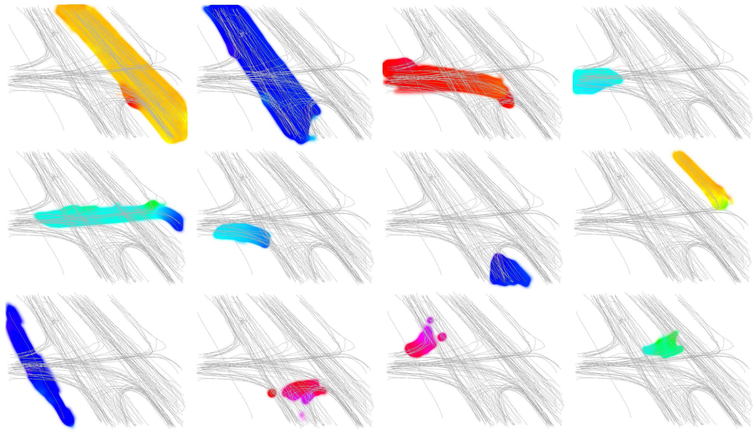


Figure 11

Atlantic Hurricane Dataset[2]:
This dataset is available from National Hurricane Service and contains historic Atlantic Hurricane Tracks from 1851 to 2012. After splitting the dataset by months, the proposed algorithm successfully retrieved motion patterns corresponding to prevailing hurricane paths for each month.



Figure 12

5. References

[1] Vehicle Motion Trajectory Dataset," http://159.226.19.33/dataset/trajectory/dataInfo.htm.

[2] "Atlantic Hurricane Dataset (HURDAT2)," http://www.nhc.noaa.gov/data/hurdat.