Trajectory Prediction Using Feature Vectors

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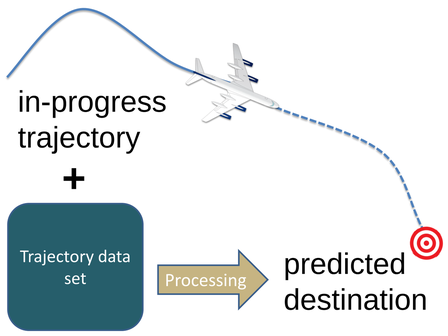
Problem

Given a database of historical trajectories, can the destination location of a new in-progress trajectory be efficiently predicted?



Challenges

- Large trajectory data set
  millions or even hundreds of millions of trajectories
- Unconstrained routes
  trajectories are not bound to a network of roads, etc.
- Accuracy and Speed Required
  must make accurate predictions quickly

Opportunities

- Route Consistency
  similar route generally taken for same origin destination pair
- Route Similarity
  most trajectories closely match some previously seen trajectories
- Large trajectory data set

Applications


Pedestrians


Eye Tracking


Vehicle


Aircraft

Data

Aircraft Situation Display to Industry (ASDI)

- includes most active flights in the National Airspace System (NAS)
- time-stamped positions, velocities, flight call signs (DAL1835), etc.
- ~5 million position reports per day

Method

In a high-dimensional feature space:

- Generate multiple feature vectors for each trajectory in the training data set
- Find nearest neighbors in the feature space to the in-progress trajectory
- Analyze to obtain probable destination

Training

Position Reports

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Separate into flights

Group position reports by call sign and break into flights at time gaps

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Clean Trajectories

Filter out invalid position reports, flights with few position reports, flights with invalid airports, and general aviation flights

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Create Feature Vectors

Create feature vectors for random-length parts of each trajectory, where each feature vector is the latitude and longitude of each of N sample points equally spaced in time along the trajectory part, plus total flight duration.

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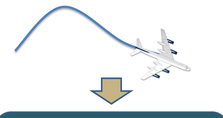
Build R-Tree

Insert the feature vectors into and instance of an R-tree.

Predicting



Create Feature Vector

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Find Similar Trajectories

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R-Tree

Find the k-nearest neighbors in the R-Tree, and analyze their associated confidence values to make a prediction

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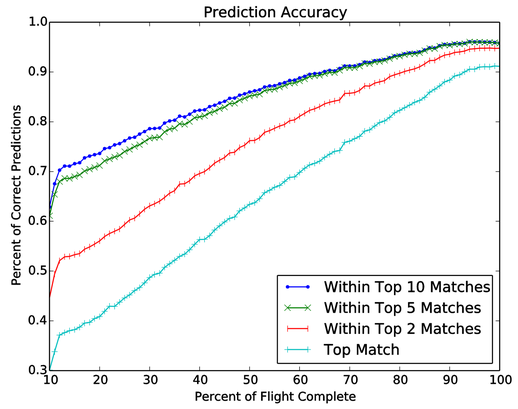
Make Prediction

Prediction Accuracy

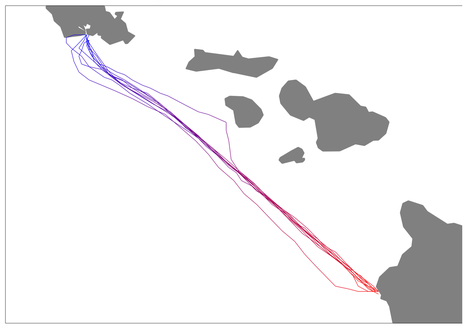
- Analyzed using 323,000 aircraft trajectories from July 2015.
- Leave-one-out analysis
- Destination predicted for a portion of each trajectory (starting at source and extending a random fraction of the way through the flight)
- 10 nearest neighbors
- Features: 4 latitude longitude pairs per trajectory, plus duration



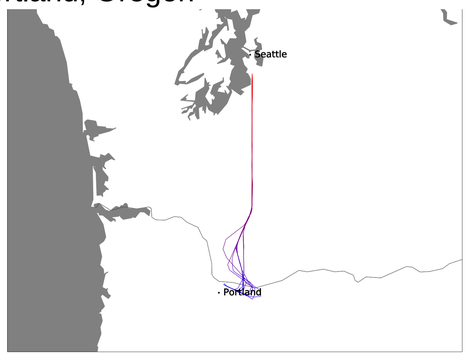
Matching Trajectories

Flights found from a database of ~8,600 flights across the United States matching the first half of an inter-island flight from Kona to Honolulu, Hawaii. Test trajectory and matches are shown.

red=origin …. blue=destination



Successful prediction of the destination of a flight from Seattle, Washington to Portland, Oregon

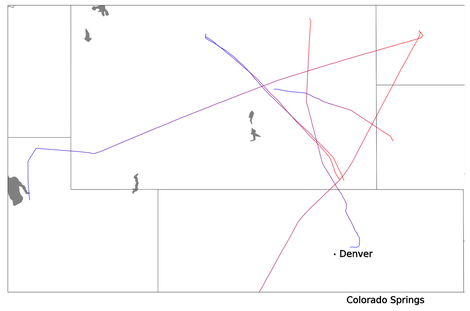


Tracktable

Tracktable [2] is a trajectory analysis library. An open source tool for ingesting, processing, plotting and analyzing any type of trajectories.

Prediction Failure

Example of an aircraft trajectory from Rapid City Regional Airport (RAP) (upper right) in South Dakota and arriving at Salt Lake International Airport (SLC) (left). Top 5 matches from among the 21,569 trajectories on the same day also shown. None of the matching trajectories even share the same destination, some fly the opposite direction. This failure is likely due to insufficient training data.



Conclusion

We have proposed a new method for destination prediction and tested it using aircraft trajectories. Given only the first half of an aircraft's flight trajectory our method can correctly predict the destination 63% of the time, and predict the correct destination in the top 5 matches 85% of the time. Our method is also efficient in that it does not rely on directly comparing new trajectories to all historical trajectories.

Future Work

We plan to improve the efficiency of our method by parallelizing the pre-processing stages, and the R-tree look-up, and the accuracy by further refining the analysis of candidate matches.

[1] J. Froehlich and J. Krumm, Route prediction from trip observations, in Society of Automotive Engineers (SAE) 2008 World Congress, 2008.
[2] Rintoul, M. D. and Wilson, A. T. (2015), Trajectory analysis via a geometric feature space approach. Statistical Analysis and Data Mining: The ASA Data Science Journal, 8: 287–301.

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