Open source tools for trajectory data analysis

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Outline

Transportation Data

Sample Applications

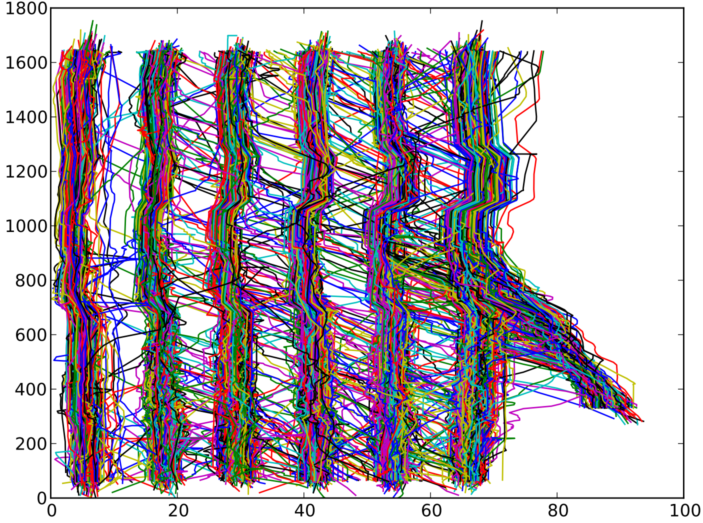
Open Source Software

Conclusion

What is transportation?

- People and goods at different places at different times
- Sets of locations at given times: trajectories are one of the most important transportation data types
- More and more easily available, at different spatial and temporal scales
  - GPS data, vehicle probes, Automatic Vehicle Identification sensors (Bluetooth, Automated License Plate Readers)
  - Video-based tracking
- Need to compare trajectories for high-level analysis, e.g. mobility patterns

Example: 2052 Trajectories (15 min)



Trajectory Data

- Processing trajectories raises the following issues:
  - different sampling rates/speeds
  - outliers and noise
  - different lengths: trajectories cannot be processed in fixed-size tables (e.g. spreadsheets), re-sampling loses information, actual positions
  - efficiency: tradeoff between accuracy and computing cost
- More suitable techniques exist
  - use the right data structure: $[(t_1, x(t_1), y(t_1)), \dots, (t_n, x(t_n), y(t_n))]$
  - use suitable similarity and distance measures, e.g. the longest common subsequence similarity (LCSS), that may leave some elements unmatched

The LCSS

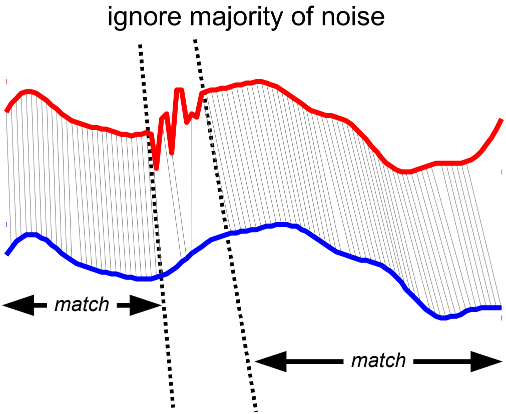
- The LCSS is a modified edit distance (used for spellchecking, handwriting recognition, DNA sequence matching, etc.)
- The LCSS is robust to noise
    - sequences are matched by allowing them to stretch, without rearranging the sequence of the elements, but allowing some elements to be unmatched
- The LCSS is very flexible
    - similarity is subjective and depends on the application

[Vlachos et al., 2005]

The LCSS

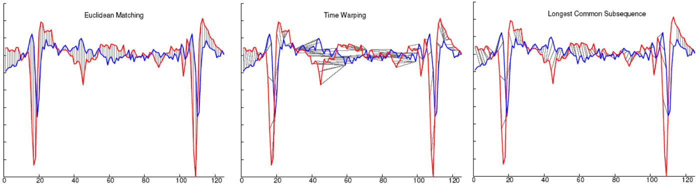
- Trajectory at regular time-steps: $P_i = \{p_{i,1}, ...p_{i,n}\}$ where $p_{i,k} = (x_{i,k}, y_{i,k})$
- $Head(P_i) = \{p_{i,1}, ...p_{i,n-1}\}$
- With a threshold $\epsilon > 0$, P_i and P_j two trajectories of lengths m and n, $LCSS_\epsilon(P_i, P_j)$ is defined as
  - 0 if $m = 0$ or $n = 0$
  - $1 + LCSS_\epsilon(Head(P_i), Head(P_j))$ if the points $p_{i,n}$ and $p_{j,m}$ match
  - $max(LCSS_\epsilon(Head(P_i), P_j), LCSS_\epsilon(P_i, Head(P_j)))$ otherwise
- Example matching: p_{i,k_1} and p_{j,k_2} match if $|x_{i,k_1} - x_{j,k_2}| < \epsilon$ and $|y_{i,k_1} - y_{j,k_2}| < \epsilon$
- Metric $DLCSS_\epsilon(P_i, P_j) = 1 - \left(\frac{LCSS_\epsilon(P_i,P_j}{min(n,m)}\right)$

The LCSS



The LCSS

Method	*Complexity*	*Elastic Matching*	*One-to-one Matching*	*Noise Robustness*
Euclidean	*O(n)*	×	✓	×
DTW	*O(n*δ)*	✓	×	×
LCSS	*O(n*δ)*	✓	✓	✓

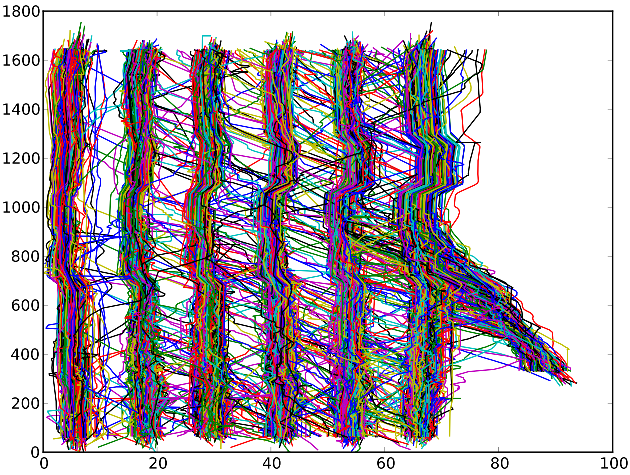


(Vlachos 2005 Tutorial)

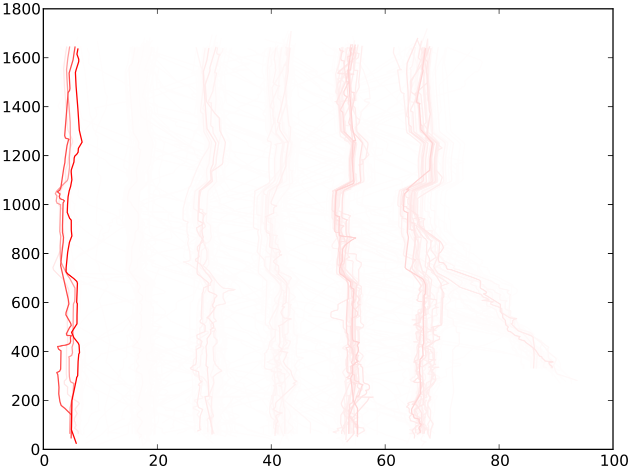
Sample Applications

- Need to compare trajectories for
  - activity / travel behaviour monitoring and modelling
    - detect “abnormal” behaviour, e.g. infractions
  - road safety diagnosis
- Algorithms
  - clustering, e.g. k-means algorithm [Saunier et al., 2007]
  - (dis-)similarity query
- Ongoing work
  - trajectory management and analysis library
  - video-based road user tracking tool

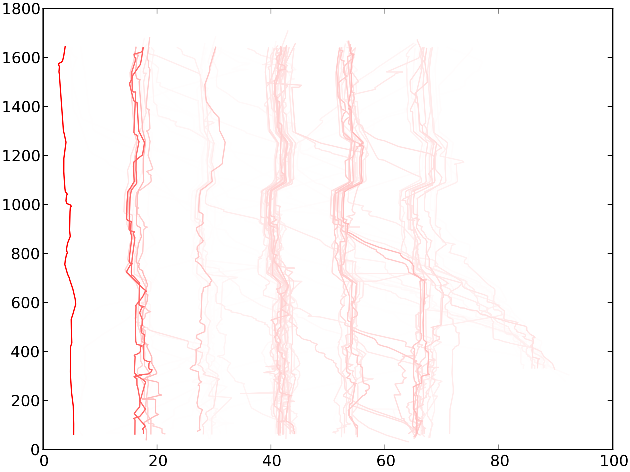
Clustering Examples: NGSIM Dataset (2052)



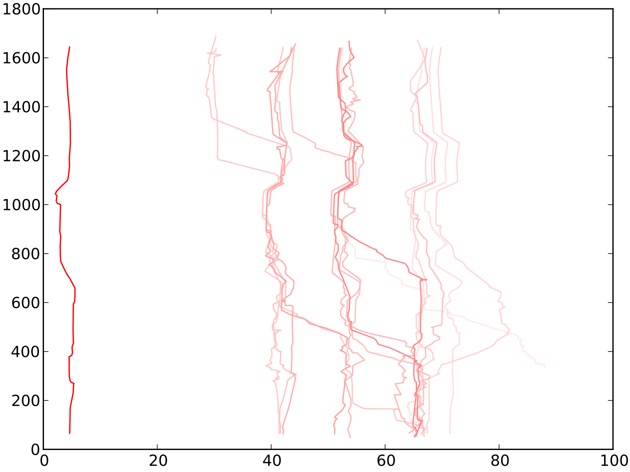
Clustering Examples: NGSIM Dataset (333)



Clustering Examples: NGSIM Dataset (96)

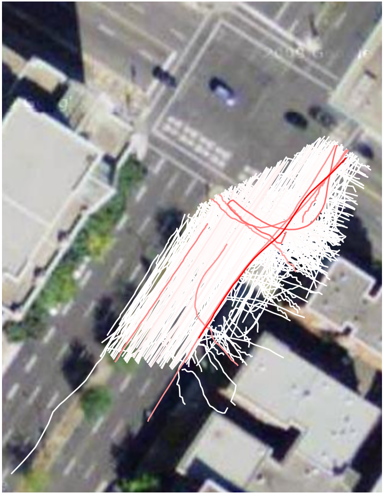


Clustering Examples: NGSIM Dataset (19)

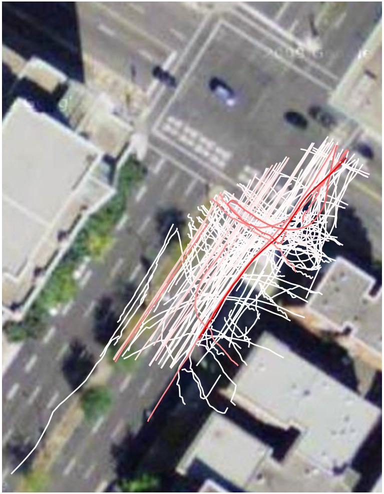


Clustering Examples: Montréal Intersection (6777)

Clustering Examples: Montréal Intersection (587)

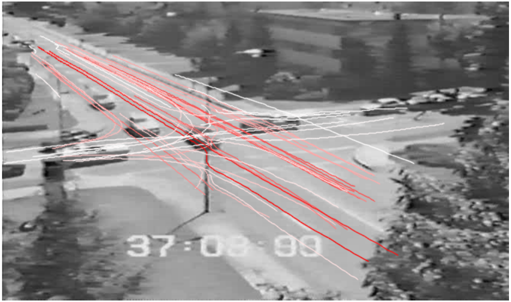


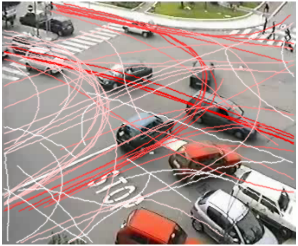
Clustering Examples: Montréal Intersection (168)



Clustering Examples: Montréal Intersection (9)

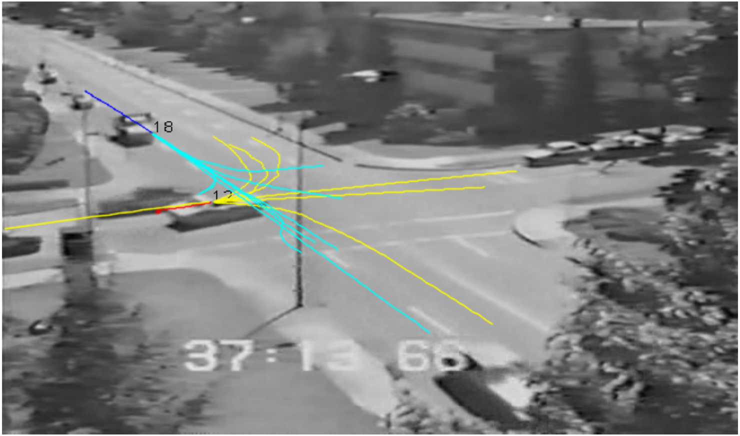
Motion Pattern Learning





Traffic Conflict Dataset, Vancouver	Reggio Calabria, Italy
58 prototype trajectories (2941 trajectories)	58 prototype trajectories (138009 trajectoires)

Application to Road Safety Diagnosis



Conflict data (Vancouver)

Open Source Software (OSS)

- OSS defining characteristics (Open Souce Initiative)
  - Free redistribution
  - Source code
  - Derived work
- OSS is everywhere and you are using it daily
  - Google, Linux web servers, Android, Facebook...
- OSS often generates strong reactions: this is not about giving away software for free, or being anti-profit, but about a superior software engineering method
  - for example, The Apache foundation is suported by Microsoft, Facebook, Yahoo!, Google, IBM, HP, AMD, etc.

Benefits of Open Source Software

1. Reproducibility of scientific results and fair comparison of algorithms
2. Uncovering problems
3. Building on existing resources (rather than re-implementing them)
4. Guaranteed access to software and tools
5. Combination of advances
6. Faster adoption of methods in different disciplines and in industry
7. Collaborative emergence of standards

[Sonnenburg et al., 2007]

Benefits of Open Source Software

- OSS should be an obvious choice for academia (being publicly funded) and considered by industry
- Buyers should be very careful about standards and continued access to technology, and open source is an important part of the solution
- There are successful mixed business models with open source core libraries and paid graphical interfaces, technical support, consulting services, etc.

Ongoing development

- Trajectory management and analysis library
  `https://bitbucket.org/trajectories/trajectorymanagementandanalysis`
- Video-based road user tracking tool
  `https://bitbucket.org/Nicolas/trafficintelligence`

Under BSD/MIT License

Conclusion

- Trajectory data is everywhere and we need the right tools to process it
- Open source software is a necessary part of Open Science, i.e. doing better science
- Open source software is an attractive software engineering method for more and more companies
- Development in progress at École Polytechnique de Montréal
  - opportunities for partners
- Perspectives
  - test more clustering algorithms and metrics
  - applications to pedestrian crossing infractions, GPS data

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Questions?

`http://nicolas.saunier.confins.net`

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