Understanding Collision Processes using Video Data

Workshop on Comparison of Surrogate Measures of Safety Extracted from Video Data

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POLYTECHNIQUE MONTRÉAL
WORLD-CLASS ENGINEERING

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Outline

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Traffic Conflicts

A traffic conflict is "an observational situation in which two or more road users approach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged" [Amundsen and Hydén, 1977]

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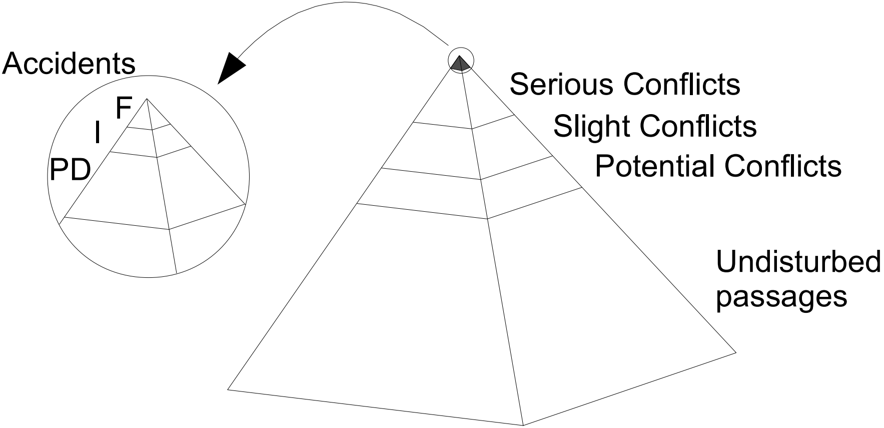
- Several traffic conflict techniques and lack of comparison
- Issues caused by the (mostly) manual data collection process
  - cost
  - reliability and subjectivity: intra- and inter-observer variability
- Mixed validation results

The Safety/Severity Hierarchy



Various surrogate safety measures

Past research [Davis et al., 2008]

There is some evidence that evasive actions undertaken by road users involved in conflicts may be of a different nature than the ones attempted in collisions

Past research: The Whole Hierarchy

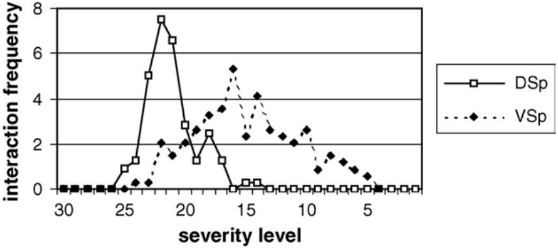


Fig. 6. Interaction frequency (interactions per observation hour) for different severity levels. Straight ahead driving vehicles versus pedestrians. The pedestrian is taking evasive action. A non-signalised intersection (DSp) and a signalised intersection (VSp).

[Svensson, 1998, Svensson and Hydén, 2006]

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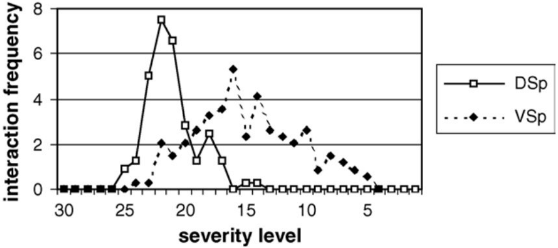

Fig. 6. Interaction frequency (interactions per observation hour) for different severity levels. Straight ahead driving vehicles versus pedestrians. The pedestrian is taking evasive action. A non-signalised intersection (DSp) and a signalised intersection (VSp).

Feedback and learning process: collisions with injuries occurred at the signalized intersection [Svensson, 1998, Svensson and Hydén, 2006]

Objectives

- Understand collision processes by studying the similarities of interactions with and without a collision to
  - design better counter-measures
  - develop better surrogate measures based on better-known relationships between interactions with and without a collision

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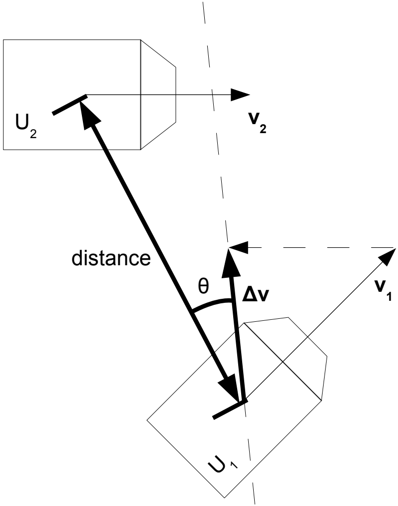
  - design better counter-measures
  - develop better surrogate measures based on better-known relationships between interactions with and without a collision
- Methods
  - collect large amounts of interaction data, in particular using video sensors
  - design suitable interaction descriptors and safety indicators (obtained through a robust probabilistic framework)
  - design suitable interaction similarity measures
  - use and adapt data mining techniques to cluster the interactions

Outline

Interaction Descriptors



Rethinking the Collision Course

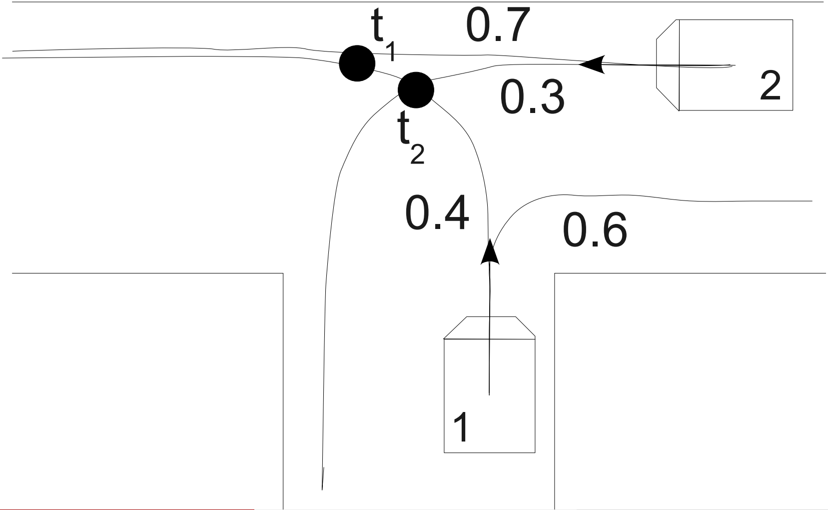
- A traffic conflict is "an observational situation in which two or more road users approach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged"
- For two interacting road users, many chains of events may lead to a collision
- It is possible to estimate the probability of collision if one can predict the road users' future positions
  - the motion prediction method must be specified

Motion Prediction

- Predict trajectories according to various hypotheses
  - iterate the positions based on the driver input (acceleration and steering)
  - learn the road users' motion patterns (including frequencies), represented by actual trajectories called prototypes, then match observed trajectories to prototypes and resample
- Advantage: generic method to detect a collision course and measure severity indicators, as opposed to several cases and formulas (e.g. in [Gettman and Head, 2003])

[Saunier et al., 2007, Saunier and Sayed, 2008, Mohamed and Saunier, 2013, St-Aubin et al., 2014]

A Simple Example



Collision Points and Crossing Zones

Using of a finite set of predicted trajectories, enumerate the collision points CP_n and the crossing zones CZ_m. Severity indicators can then be computed:

$$P(Collision(U_i, U_j)) = \sum_n P(Collision(CP_n))$$

$$TTC(U_i, U_j, t_0) = \frac{\sum_n P(Collision(CP_n))\ t_n}{P(Collision(U_i, U_j))}$$

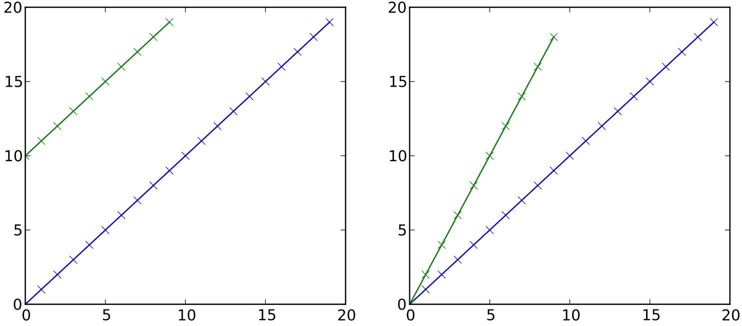
$$pPET(U_i, U_j, t_0) = \frac{\sum_m P(Reaching(CZ_m))\ |t_{i,m} - t_{j,m}|}{\sum_m P(Reaching(CZ_m))}$$

[Saunier et al., 2010, Mohamed and Saunier, 2013, Saunier and Mohamed, 2014]

Similarity Measures

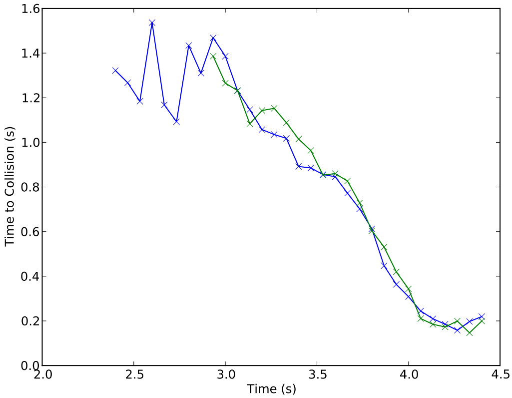
- Traditional measures rely on fixed length descriptor vectors: extract agregated values from continuous time series indicator data
  - considerable loss of information
- Some measures naturally accomodate variable length vectors: Longest Common Sub-sequence

Need for Improved LCSS



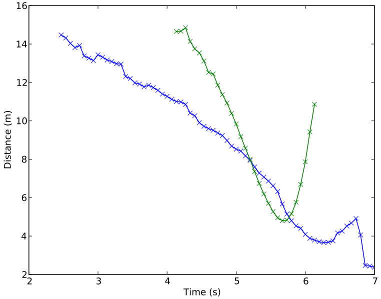
The series in each plot have maximum similarity if using $\delta = +\infty$: this is desired in the plot on the left since it is an exact sub-sequence, but not on the right if the rate of change is taken into account

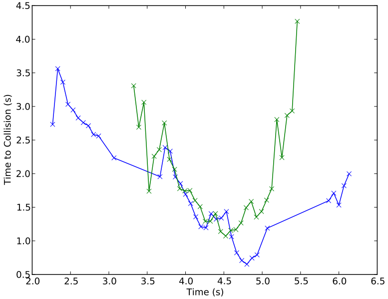
The Aligned LCSS



Example of alignment of two very similar real TTC indicators: $LCSS_{2,d_{0.2\ s}} = 0.2$ and $ALCSS_{2,d_{0.2\ s}} = 1$

The Aligned LCSS





	Distance	TTC
$LCSS_{+\infty}$	0.87	0.64
$LCSS_2$	0.35	0.12
$ALCSS_2$	0.42	0.42

These real profiles are more similar using *LCSS* with infinite δ than using *ALCSS* and a finite δ

Clustering Algorithm

- All algorithms operating on a similarity matrix may be used
- Custom algorithm with cluster prototypes [Saunier et al., 2007]
  1. Indicators are sorted by length
  2. For each indicator, if its maximum similarity is lower than a threshold, create a new cluster with indicator as prototypes
  3. Otherwise, assign it to the most similar prototype

Outline

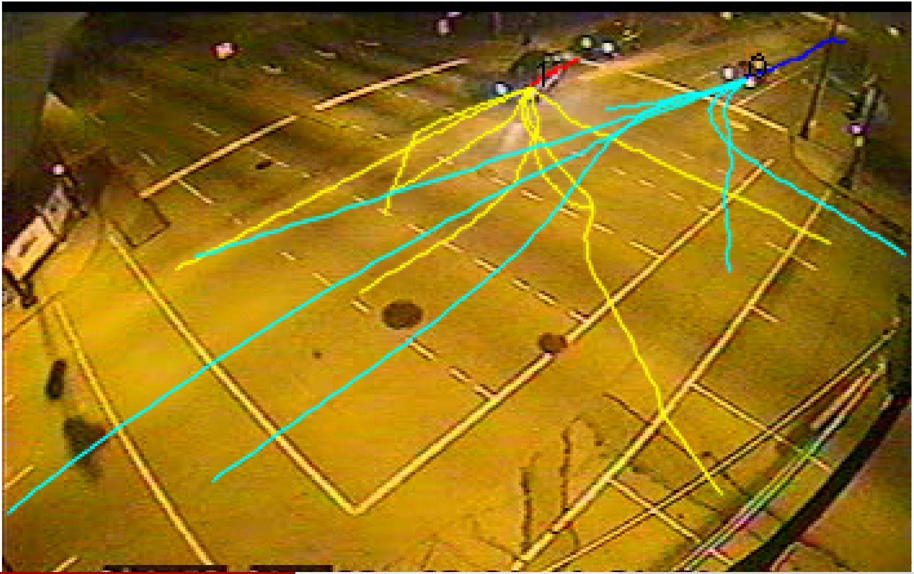
The Kentucky Dataset

- Video recordings kept for a few seconds before and after the sound-based automatic detection of an interaction of interest
- 213 traffic conflicts and 82 collisions
- The existence of an interaction or its severity is not always obvious
- The interactions recorded in this dataset involve only motorized vehicles
- Limited quality of the video data: resolution, compression, weather and lighting conditions

Road User Tracking

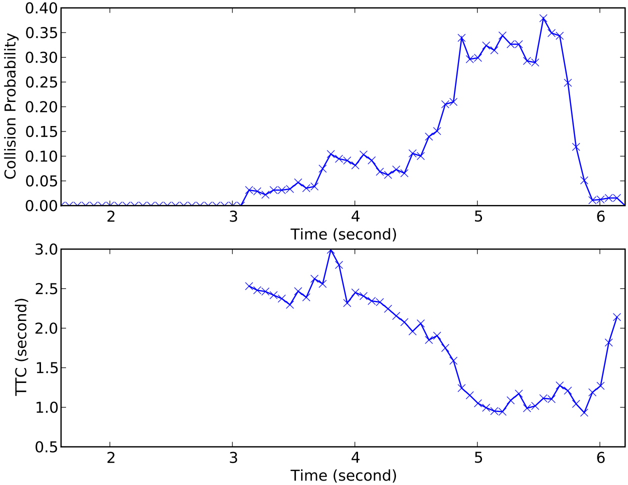
Motion Prediction

Motion Prediction



Motion Prediction

Severity Indicators



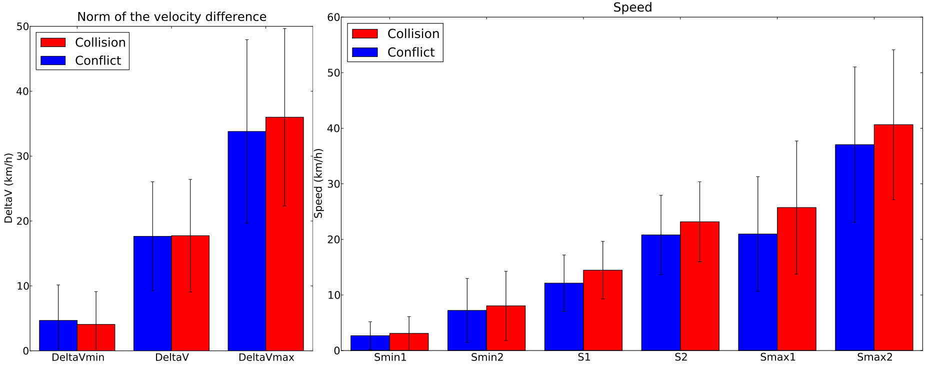
Description of Interactions [?]

Categorical attributes	Values
Type of day	weekday, week end
Lighting condition	daytime, twilight, nighttime
Weather condition	normal, rain, snow
Interaction category	same direction (turning left and right, rear-end, lane change), opposite direction (turning left and right, head-on), side (turning left and right, straight)
Interaction outcome	conflict, collision

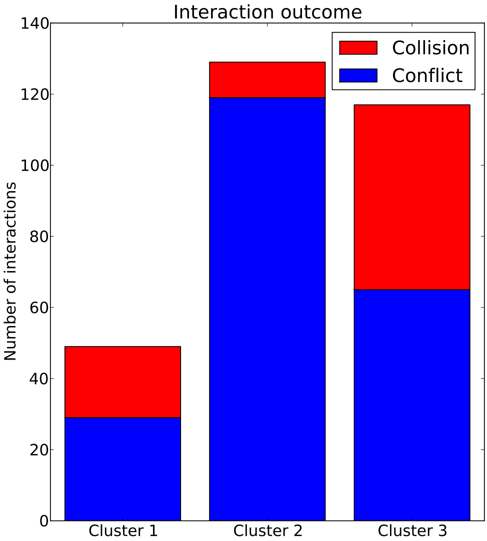
Description of Interactions

Numerical attributes	**Units**
Road user type	
passenger car	number of road users
van, 4x4, SUV	number of road users
bus	number of road users
truck (all sizes)	number of road users
motorcycle	number of road users
Type of evasive action	
No evasive action	number of evasive actions
Braking	number of evasive actions
Swerving	number of evasive actions
Acceleration	number of evasive actions
3 attributes from Δv	km/h
6 values from s	km/h

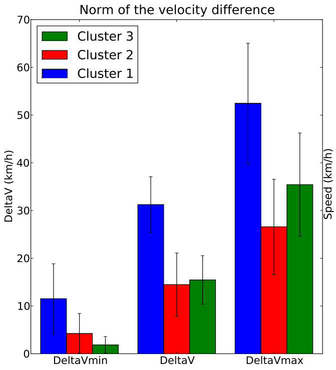
Distribution of Speed Attributes

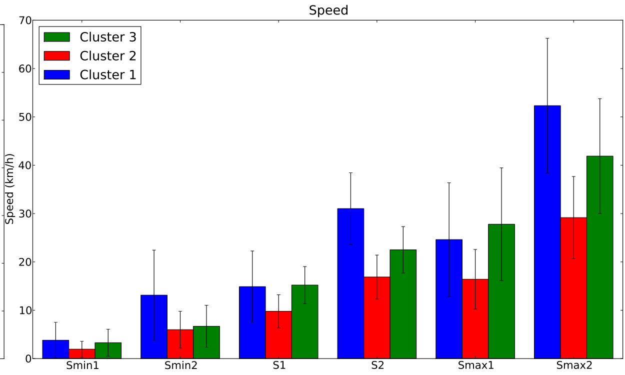


3 Clusters

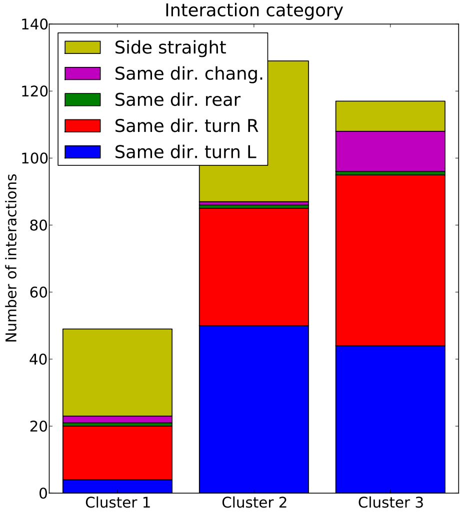

Interaction outcome
Collision
Conflict
Number of interactions
0
20
40
60
80
100
120
140
Cluster 1
Cluster 2
Cluster 3

Clusters: Speed Attributes





Clusters: Interaction Category

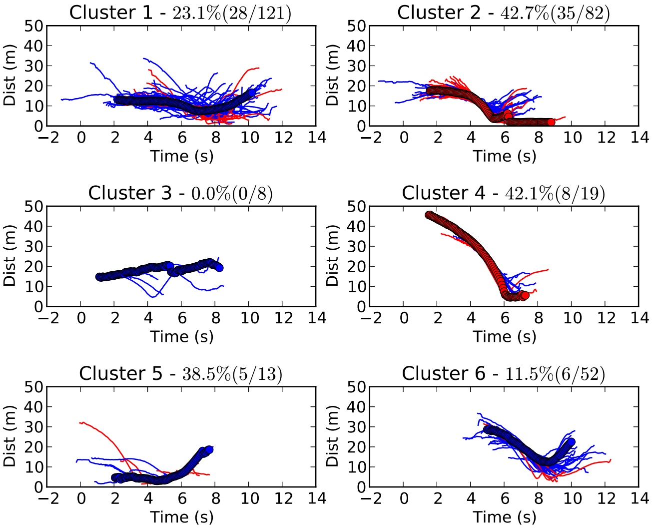


- Cluster 1: collisions, highest speeds, categories side straight and same direction turning right
- Cluster 2: almost pure conflicts, lowest speeds
- Cluster 3: collisions, medium speeds, categories same direction turning left and right and same direction changing lanes

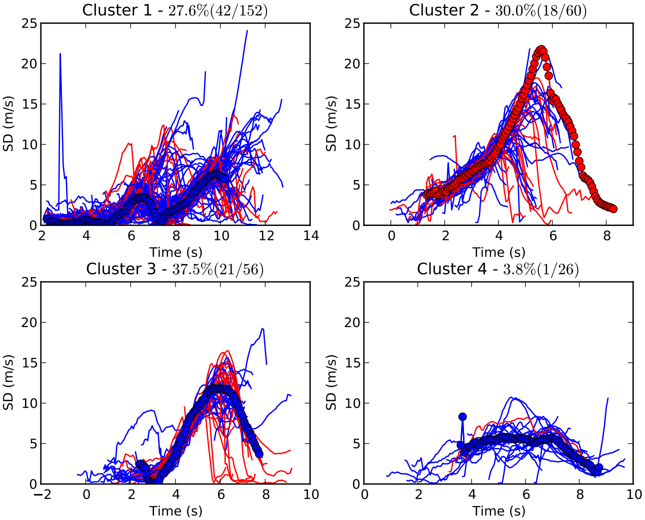
Indicator Clustering using Aligned LCSS [Saunier and Mohamed, 2014]

Indicator	Threshold ϵ	Minimum Clustering Similarity	Number of Clusters
Distance (Dist)	1 m	0.23	6
Speed differential (SD)	1.5 m/s	0.4	4
Velocity angle (VA)	0.15 rad	0.4	4
Time to collision (TTC)	0.2 s	0.3	4
Probability of Collision (PoC)	0.1	0.5	6

Indicator Clustering using Aligned LCSS



Indicator Clustering using Aligned LCSS



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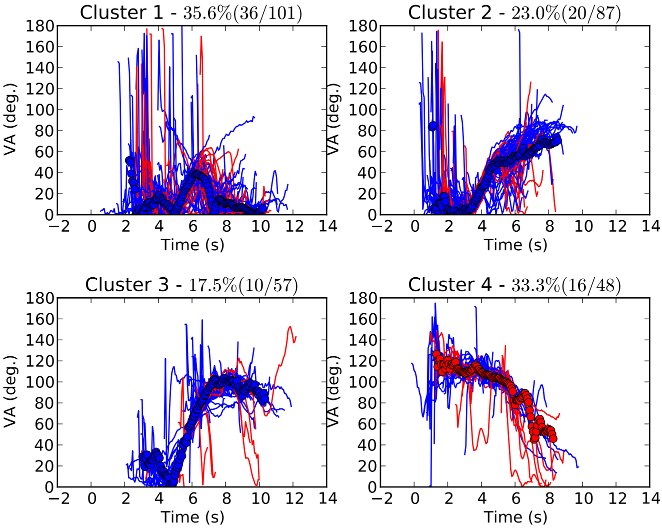

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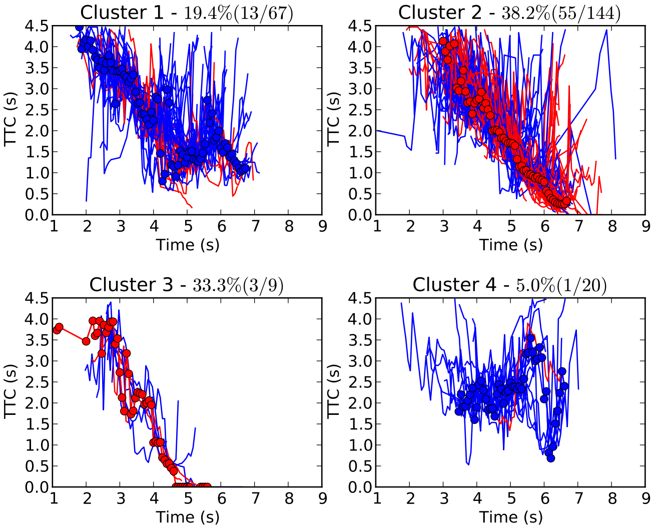

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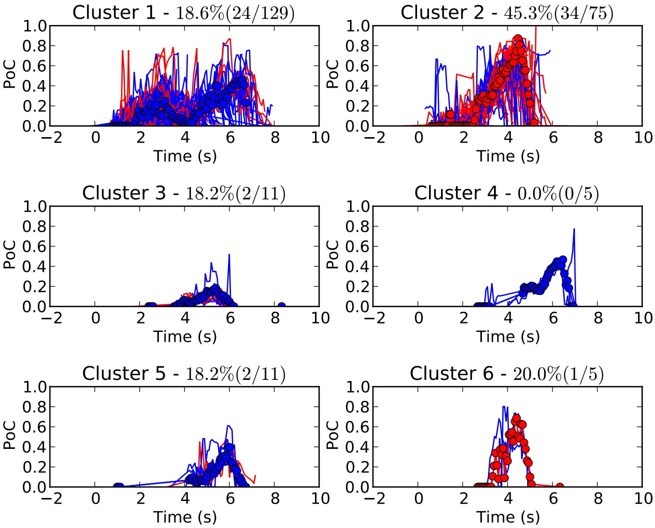

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Conclusion

- Better tools to measure interaction similarity (and general time series similarity)

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- Mounting evidence that not all interactions should be used for surrogate safety measure

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- Better tools to measure interaction similarity (and general time series similarity)
- Mounting evidence that not all interactions should be used for surrogate safety measure
- Future work: collect more data and compare methods

Need for Open Science

- Scientific principle of reproducibility
    - to what extent are the mixed validation results reported in the literature related to a lack of comparisons and reproduciblity of the various methods proposed for surrogate safety analysis?
- Need to share data and tools used to produce the results
    - public datasets and benchmarks
    - public / open source software
- Traffic Intelligence open source project `https://bitbucket.org/Nicolas/trafficintelligence`

- Collaboration with Nadia Mourji, Bruno Agard, Mohamed Gomaa Mohamed, Paul St-Aubin (Polytechnique Montréal)
- Funded in part by the Natural Sciences and Research Council of Canada (NSERC)

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Questions?

Video Sensors

Video sensors have distinct advantages:

- they are easy to install (or can be already installed)
- they are inexpensive
- they can provide rich traffic description (e.g. road user tracking)
- they can cover large areas
- their recording allows verification at a later stage

Video-based System

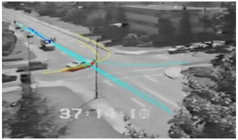
Image Sequence
+

Camera Calibration

+

Labeled Images for Road User Type

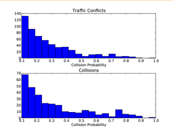
Road User Trajectories



Interactions

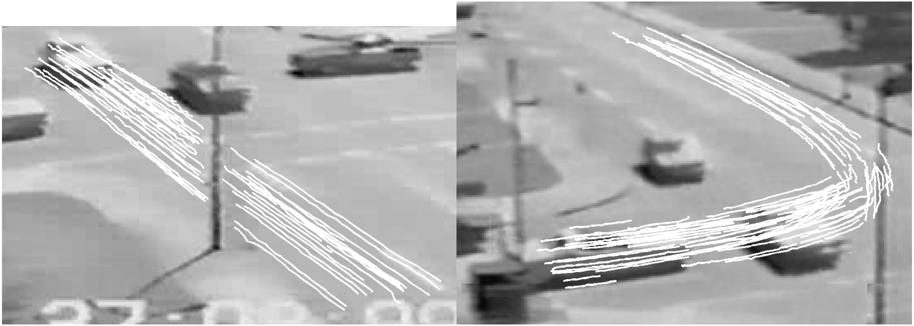
Applications

Motion patterns, volume, origin-destination counts, driver behavior



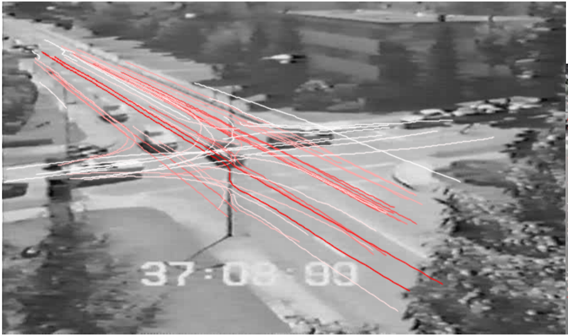
Traffic conflicts, exposure and severity measures, interacting behavior

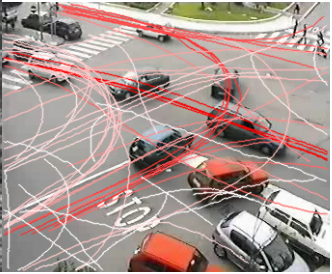
Feature-based Road User Tracking in Video Data



Good enough for safety analysis and other applications, including the study of pedestrians and pedestrian-vehicle interactions [Saunier and Sayed, 2006]

Motion Pattern Learning





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

Amundsen, F. and Hydén, C., editors (1977).
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