Understanding Collision Processes using Video Data
Workshop on Comparison of Surrogate Measures of Safety
Extracted from Video Data

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Outline

1. Motivation
2. Methodology
3. Experimental Results using Video Data
4. Conclusion
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1. Motivation
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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]
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]

- 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
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).

Past research: The Whole Hierarchy

Motivation


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).
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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**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
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Interaction Descriptors

\[ \theta, \Delta v, U_1, U_2, \text{distance} \]
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

- $t_1$: 0.7
- $t_2$: 0.3
- 0.4
- 0.6

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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:

\[
P(\text{Collision}(U_i, U_j)) = \sum_{n} P(\text{Collision}(CP_n))
\]

\[
TTC(U_i, U_j, t_0) = \frac{\sum_{n} P(\text{Collision}(CP_n)) t_n}{P(\text{Collision}(U_i, U_j))}
\]

\[
pPET(U_i, U_j, t_0) = \frac{\sum_{m} P(\text{Reaching}(CZ_m)) |t_{i,m} - t_{j,m}|}{\sum_{m} P(\text{Reaching}(CZ_m))}
\]

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

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

$\text{LCSS}_{2, d_{0.2}} = 0.2$ and $\text{ALCSS}_{2, d_{0.2}} = 1$
The Aligned LCSS

These real profiles are more similar using LCSS with infinite $\delta$ than using ALCSS and a finite $\delta$.
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
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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

![Graphs showing collision probability and TTC over time.](image)
## Description of Interactions

<table>
<thead>
<tr>
<th>Categorical attributes</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Type of day</em></td>
<td>weekday, week end</td>
</tr>
<tr>
<td><em>Lighting condition</em></td>
<td>daytime, twilight, nighttime</td>
</tr>
<tr>
<td><em>Weather condition</em></td>
<td>normal, rain, snow</td>
</tr>
<tr>
<td><em>Interaction category</em></td>
<td>same direction (turning left and right, rear-end, lane change), opposite direction (turning left and right, head-on), side (turning left and right, straight)</td>
</tr>
<tr>
<td><em>Interaction outcome</em></td>
<td>conflict, collision</td>
</tr>
</tbody>
</table>
## Description of Interactions

<table>
<thead>
<tr>
<th>Numerical attributes</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road user type</td>
<td></td>
</tr>
<tr>
<td>passenger car</td>
<td>number of road users</td>
</tr>
<tr>
<td>van, 4x4, SUV</td>
<td>number of road users</td>
</tr>
<tr>
<td>bus</td>
<td>number of road users</td>
</tr>
<tr>
<td>truck (all sizes)</td>
<td>number of road users</td>
</tr>
<tr>
<td>motorcycle</td>
<td>number of road users</td>
</tr>
<tr>
<td>Type of evasive action</td>
<td></td>
</tr>
<tr>
<td>No evasive action</td>
<td>number of evasive actions</td>
</tr>
<tr>
<td>Braking</td>
<td>number of evasive actions</td>
</tr>
<tr>
<td>Swerving</td>
<td>number of evasive actions</td>
</tr>
<tr>
<td>Acceleration</td>
<td>number of evasive actions</td>
</tr>
<tr>
<td>3 attributes from $\Delta v$</td>
<td>km/h</td>
</tr>
<tr>
<td>6 values from $s$</td>
<td>km/h</td>
</tr>
</tbody>
</table>
Experimental Results using Video Data

Distribution of Speed Attributes

- **Norm of the velocity difference**
  - DeltaVmin
  - DeltaV
  - DeltaVmax
  - DeltaV (km/h)
  - Collision
  - Conflict

- **Speed**
  - Smin1
  - Smin2
  - S1
  - S2
  - Smax1
  - Smax2
  - Speed (km/h)
  - Collision
  - Conflict

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3 Clusters

![Bar chart showing interaction outcomes for three clusters. Cluster 1 has 30 interactions, 20 of which are collisions and 10 of which are conflicts. Cluster 2 has 120 interactions, all of which are collisions. Cluster 3 has 80 interactions, 50 of which are collisions and 30 of which are conflicts.]

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Clusters: Speed Attributes

**Norm of the velocity difference**

- **Cluster 3**
- **Cluster 2**
- **Cluster 1**

**DeltaVmin**, **DeltaV**, **DeltaVmax**

**Speed (km/h)**

- **Cluster 3**
- **Cluster 2**
- **Cluster 1**

**Smin1**, **Smin2**, **S1**, **S2**, **Smax1**, **Smax2**
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]

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Threshold $\epsilon$</th>
<th>Minimum Clustering Similarity</th>
<th>Number of Clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (Dist)</td>
<td>1 m</td>
<td>0.23</td>
<td>6</td>
</tr>
<tr>
<td>Speed differential (SD)</td>
<td>1.5 m/s</td>
<td>0.4</td>
<td>4</td>
</tr>
<tr>
<td>Velocity angle (VA)</td>
<td>0.15 rad</td>
<td>0.4</td>
<td>4</td>
</tr>
<tr>
<td>Time to collision (TTC)</td>
<td>0.2 s</td>
<td>0.3</td>
<td>4</td>
</tr>
<tr>
<td>Probability of Collision (PoC)</td>
<td>0.1</td>
<td>0.5</td>
<td>6</td>
</tr>
</tbody>
</table>
Experimental Results using Video Data

Indicator Clustering using Aligned LCSS

Cluster 1 - 23.1% (28/121)

Cluster 2 - 42.7% (35/82)

Cluster 3 - 0.0% (0/8)

Cluster 4 - 42.1% (8/19)

Cluster 5 - 38.5% (5/13)

Cluster 6 - 11.5% (6/52)
Indicator Clustering using Aligned LCSS

Cluster 1 - 27.6% (42/152)
Cluster 2 - 30.0% (18/60)
Cluster 3 - 37.5% (21/56)
Cluster 4 - 3.8% (1/26)
Indicator Clustering using Aligned LCSS

Cluster 1 - 35.6% (36/101)
Cluster 2 - 23.0% (20/87)
Cluster 3 - 17.5% (10/57)
Cluster 4 - 33.3% (16/48)
Experimental Results using Video Data

Indicator Clustering using Aligned LCSS

Cluster 1 - 19.4% (13/67)
Cluster 2 - 38.2% (55/144)
Cluster 3 - 33.3% (3/9)
Cluster 4 - 5.0% (1/20)
Indicator Clustering using Aligned LCSS

Cluster 1 - 18.6% (24/129)

Cluster 2 - 45.3% (34/75)

Cluster 3 - 18.2% (2/11)

Cluster 4 - 0.0% (0/5)

Cluster 5 - 18.2% (2/11)

Cluster 6 - 20.0% (1/5)
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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
Conclusion

- 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 reproducibility 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](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
58 prototype trajectories
(2941 trajectories)

Reggio Calabria, Italy
58 prototype trajectories
(138009 trajectories)


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