Outline

1. Motivation
2. Approach
3. Case Studies
4. Conclusion
Methods for Road Safety Analysis

There are two main categories of methods, whether they are based on the observation of traffic events or not

1. Accidents are reconstituted
   - traditional road safety analysis relying on historical collision data
   - vehicular accident reconstruction
Methods for Road Safety Analysis

There are two main categories of methods, whether they are based on the observation of traffic events or not.

1. Accidents are reconstituted
   - traditional road safety analysis relying on historical collision data
   - vehicular accident reconstruction

2. Accidents and other traffic events are directly observed
   - naturalistic driving studies
   - surrogate safety analysis
Main Issues with Traditional Methods for Road Safety Analysis

1. Difficult **attribute**ion of collisions to a cause
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   - reports are skewed towards the attribution of responsibility, not the search for the causes that led to a collision
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Main Issues with Traditional Methods for Road Safety Analysis

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   - reports are skewed towards the attribution of responsibility, not the search for the causes that led to a collision

2. Small data quantity

3. Limited quality of the data reconstituted after the event, with a bias towards more damaging collisions

4. Traditional road safety analysis is reactive
   - the following paradox ensues: safety analysts need to wait for accidents to happen in order to prevent them
Need for Proactive (Surrogate) Methods for Road Safety Analysis

These methods should

- bring complementary information
- be related to traffic events that are more frequent than collisions and can be observed in the field
- be correlated to collisions, logically and statistically
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]
The Safety/Severity Hierarchy

- Accidents
- Serious Conflicts
- Slight Conflicts
- Potential Conflicts
- Undisturbed passages

Motivation
Surrogate Measures of Safety

The most famous are traffic conflict severity indicators:

- **Continuous measures**
  - Time-to-collision (TTC)
  - Gap time (GT) (=predicted PET)
  - Deceleration to safety time (DST)
  - Speed, etc.

- **Unique measures per conflict**
  - Post-encroachment time (PET)
  - Evasive action(s) (harshness), subjective judgment, etc.
**Time-to-Collision**

\[ \text{TTC} = \frac{d_2}{v_2} \text{ if } \frac{d_1}{v_1} < \frac{d_2}{v_2} < \frac{d_1 + l_1 + w_2}{v_1} \]

\[ \text{TTC} = \frac{d_1}{v_1} \text{ if } \frac{d_2}{v_2} < \frac{d_1}{v_1} < \frac{d_2 + l_2 + w_1}{v_2} \text{ (side)} \]

\[ \text{TTC} = \frac{X_1 - X_2 - l_1}{v_1 - v_2} \text{ if } v_2 > v_1 \text{ (rear end)} \]

\[ \text{TTC} = \frac{X_1 - X_2}{v_1 + v_2} \text{ (head on)} \]
**Post-Encroachment Time (PET) and Predicted PET**

- **PET** is the time difference between the moment an offending road user leaves an area of potential collision and the moment of arrival of a conflicted road user possessing the right of way.
- **pPET** is calculated at each instant by extrapolating the movements of the interacting road users in space and time.
Several traffic conflict techniques exist ("old" and "new") but there is a lack of comparison and validation.

Issues related to the (mostly) manual data collection process:
- cost
- reliability and subjectivity: intra- and inter-observer variability

Mixed validation results.
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).

Motivation

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).

Objectives

- Develop a robust probabilistic framework for surrogate safety analysis
- Better understand collision processes and the similarities between interactions with and without a collision
- Validate the surrogate measures of safety
- Apply the method to several case studies: urban intersections, vulnerable road users, highway
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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”

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:

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

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

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

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

Image Sequence +

Road User Trajectories

Interactions

Camera Calibration +

Applications

Labeled Images for Road User Type

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

Traffic conflicts, exposure and severity measures, interacting behavior

Approach

N. Saunier, Polytechnique Montréal

February 24th 2014

20 / 47
Feature-based Road User Tracking in Video Data

Good enough for safety analysis and other applications in busy urban road locations, including the study of pedestrians and pedestrian-vehicle interactions [Saunier and Sayed, 2006]
Road User Classification [Saunier et al., 2011]
Road User Classification [Zangenehpour et al., 2014]

(a) Snapshot of video frame

(b) Vehicle trajectory heat-map

(c) Cyclist trajectory heat-map

(d) Pedestrian trajectory heat-map
Flexible Mobile Video Data Collection Unit

[Jackson et al., 2013]
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Case Studies

Road User Tracking (Kentucky Dataset)
Motion Prediction
Motion Prediction
Motion Prediction
Severity Indicators
Case Studies

Distribution of Indicators

Maximum Collision Probability

Minimum TTC
Spatial Distribution of the Collision Points

Traffic Conflicts

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February 24th 2014 31 / 47
Spatial Distribution of the Collision Points
Before and After Study: Introduction of a Scramble Phase

Data collected in Oakland, CA [Ismail et al., 2010]
Distribution of Severity Indicators

Histogram of Before-and-After TTC

Histogram of Before-and-After DST

Histogram of Before-and-After PET

Histogram of Before-and-After GT
Before and After Distribution of the Collision Points

a) Before Scramble

b) After Scramble

c) Before Scramble

d) After Scramble
Case Studies

Lane-Change Bans at Urban Highway Ramps

Ramp: A20-E-E56-3
Region(s): UPreMZ, PPreMZ
Treatment: Yes
Analysis length: 50 m

Treated site (with lane marking)
[St-Aubin et al., 2012, St-Aubin et al., 2013a]

Figure 37 – Conflict analysis Cam20-16-Dorval (Treated).
Lane-Change Bans at Urban Highway Ramps

Ramp: A20-E-E56-3
Region(s): UPreMZ
Treatment: No
Analysis length: 50 m

Untreated site (no lane marking)
[St-Aubin et al., 2012, St-Aubin et al., 2013a]
Dangerous Pedestrian Crossings and Violations at Signalized Intersections

[Brosseau et al., 2013]
Dangerous Pedestrian Crossings and Violations at Signalized Intersections

[Brosseau et al., 2013]
Roundabouts Safety in Québec

Case Studies
Roundabout Safety [St-Aubin et al., 2014]
Case Studies

Cycle Track Safety (First Results)

N. Saunier, Polytechnique Montréal

February 24th 2014
Cycle Track Safety (First Results)

Table 1. Surrogate measures for the intersections with and without a cycle track

<table>
<thead>
<tr>
<th>Minutes</th>
<th>Cyclists</th>
<th>Right Turning Vehicles</th>
<th>Conflicts (TTC &lt; 5s)</th>
<th>Dang. Conf. (TTC &lt; 1.5s)</th>
<th>Conflict Rate*</th>
<th>Dang. Conf. Rate*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without Cycle Track</td>
<td>154</td>
<td>384</td>
<td>500</td>
<td>120</td>
<td>26</td>
<td>625</td>
</tr>
<tr>
<td>With Cycle Track</td>
<td>232</td>
<td>912</td>
<td>556</td>
<td>90</td>
<td>10</td>
<td>177</td>
</tr>
</tbody>
</table>

*Conflicts per million potential conflicts
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Surrogate methods for safety analysis are complementary methods to understand collision factors and better diagnose safety.
Surrogate methods for safety analysis are complementary methods to understand collision factors and better diagnose safety.

The challenge is to propose a simple and generic framework for surrogate safety analysis, instead of pretending more special cases and indicators are needed.
**Perspectives**

- Improve computer vision for **all** road users in **busy urban** locations
Perspectives

- Improve computer vision for all road users in busy urban locations
- Validation of surrogate methods for road safety analysis
Perspectives

- Improve computer vision for **all** road users in **busy urban** locations
- **Validation** of surrogate methods for road safety analysis
  - 20 roundabout sites with video observations and accident records
Perspectives

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- Understanding and modelling of collision processes: collect more data
Perspectives

- Improve computer vision for all road users in busy urban locations
- **Validation** of surrogate methods for road safety analysis
  - 20 roundabout sites with video observations and accident records
- Understanding and modelling of collision processes: collect more data
- Pedestrian modelling: collaboration with Bilal Farooq
Researchers Need to Share More

- 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 [Saunier et al., 2014]
  - **public / open source** software: adoption and contributions by researchers and practitioners

- Traffic Intelligence open source project [https://bitbucket.org/Nicolas/trafficintelligence](https://bitbucket.org/Nicolas/trafficintelligence)
Collaboration with Tarek Sayed (UBC), Karim Ismail (Carleton), Marilyne Brosseau, Mohamed Gomaa Mohamed, Paul St-Aubin (Polytechnique Montréal), Luis Miranda-Moreno, Sohail Zangenehpour (McGill), Aliaksei Laureshyn (Lund)

Funded by the Natural Sciences and Engineering Research Council of Canada (NSERC), the Québec Research Fund for Nature and Technology (FRQNT) and the Québec Ministry of Transportation (MTQ)

Questions?
Conclusion

Motion Pattern Learning

Traffic Conflict Dataset, Vancouver

58 prototype trajectories
(2941 trajectories)

Reggio Calabria, Italy

58 prototype trajectories
(138009 trajectories)


Automated analysis of pedestrian-vehicle conflicts: Context for before-and-after studies.

*Transportation Research Record: Journal of the Transportation Research Board*, 2198:52–64.
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