Automated Road Safety Analysis using Video Data
Conférence du chapitre des étudiants de Montréal du Groupe de Recherches sur les Transports au Canada
Montreal Students’ Chapter - Canadian Transportation Research Forum Conference

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April 7th 2014
Outline

1. Motivation
2. Approach
3. Case Studies
4. Conclusion
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A World Health Issue

Over 1.2 million people die each year on the world’s roads, and between 20 and 50 million suffer non-fatal injuries. In most regions of the world this epidemic of road traffic injuries is still increasing.

(Global status report on road safety, World Health Organization, 2009)
## A World Health Issue

<table>
<thead>
<tr>
<th>RANK</th>
<th>LEADING CAUSE</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ischaemic heart disease</td>
<td>12.2</td>
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<tr>
<td>2</td>
<td>Cerebrovascular disease</td>
<td>9.7</td>
</tr>
<tr>
<td>3</td>
<td>Lower respiratory infections</td>
<td>7.0</td>
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<tr>
<td>4</td>
<td>Chronic obstructive pulmonary disease</td>
<td>5.1</td>
</tr>
<tr>
<td>5</td>
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<td>6</td>
<td>HIV/AIDS</td>
<td>3.5</td>
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<tr>
<td>7</td>
<td>Tuberculosis</td>
<td>2.5</td>
</tr>
<tr>
<td>8</td>
<td>Trachea, bronchus, lung cancers</td>
<td>2.3</td>
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<tr>
<td>9</td>
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<td>2.2</td>
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<tr>
<td>10</td>
<td>Prematurity and low birth weight</td>
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<tr>
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<tr>
<td>16</td>
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</tr>
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**TOTAL 2004**

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Methods for Road Safety Analysis

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

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   - traditional road safety analysis relying on historical collision data
   - vehicular accident reconstruction
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   - traditional road safety analysis relying on historical collision data
   - vehicular accident reconstruction

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

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4. Traditional road safety analysis is reactive
Main Issues with Traditional Methods for Road Safety Analysis

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

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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

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

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

\[ \text{TTC} = \frac{X_1 - X_2}{v_1 + v_2} \quad (\text{head on}) \]
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.
Issues with Traffic Conflict Techniques

- 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
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, highways
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
Approach

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 $C_{Pn}$ and the crossing zones $C_{Zm}$. Severity indicators can then be computed:

$$P(\text{Collision}(U_i, U_j)) = \sum_{n} P(\text{Collision}(C_{Pn}))$$

$$\text{TTC}(U_i, U_j, t_0) = \frac{\sum_{n} P(\text{Collision}(C_{Pn})) t_n}{P(\text{Collision}(U_i, U_j))}$$

$$pPET(U_i, U_j, t_0) = \frac{\sum_{m} P(\text{Reaching}(C_{Zm})) |t_{i,m} - t_{j,m}|}{\sum_{m} P(\text{Reaching}(C_{Zm}))}$$

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

Image Sequence

Road User Trajectories

Interactions

Camera Calibration

Labeled Images for Road User Type

Applications

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

Traffic conflicts, exposure and severity measures, interacting behavior
Road User Tracking (Kentucky Dataset)
Motion Prediction
Motion Prediction
Motion Prediction
Severity Indicators

![Graphs showing collision probability and TTC over time](image-url)
Distribution of Indicators

**Maximum Collision Probability**

- Traffic Conflicts
- Collisions

**Minimum TTC**

- Traffic Conflicts
- Collisions

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Spatial Distribution of the Collision Points

Traffic Conflicts
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

Frequency of traffic events

TTC<sub>min</sub> in seconds

TTC Before

TTC After

Histogram of Before-and-After DST

Frequency of traffic events

DST<sub>max</sub> in seconds

PET Before

PET After

Histogram of Before-and-After PET

Frequency of traffic events

|PET| Before

|PET| After

Histogram of Before-and-After GT

Frequency of traffic events

GT<sub>min</sub> in seconds

GT Before

GT After
Case Studies

Lane-Change Bans at Urban Highway Ramps

Figure 37 – Conflict analysis Cam20-16-Dorval (Treated).

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

Ramp: A20-E-E56-3
Region(s): UPreMZ, PPreMZ
Treatment: Yes
Analysis length: 50 m
Lane-Change Bans at Urban Highway Ramps

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

Figure 27 – Conflict analysis Cam20-16-Dorval (Untreated).

Untreated site (no lane marking)
[St-Aubin et al., 2012, St-Aubin et al., 2013]
Roundabouts Safety in Québec
Roundabout Safety [St-Aubin et al., 2014]
Cycle Track Safety (First Results)
## 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

### Graph

- Intersection with cycle track (normalized, per million potential interactions)
- Intersection without cycle track (normalized, per million potential interactions)
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**Conclusion**

- **Surrogate** methods for safety analysis are complementary methods to understand collision factors and better diagnose safety.
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Automated video analysis is feasible to collect traffic data and better understand road user behaviour.
Two Final Messages for Transportation Students

1. **Computational skills are essential and increasingly so:** learn how to program!
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2. **Open science** is necessary to enable true **reproducibility** which is a cornerstone of science
   - if you cannot reproduce and check another researcher’s method, this is not science
   - as young researchers, you can choose to continue research as if the Internet and open source software do not exist, or to embrace **sharing** data and (software) tools as enabled by the Internet
Traffic Intelligence open source project
https://bitbucket.org/Nicolas/trafficintelligence

- Collaboration with Tarek Sayed (UBC), Karim Ismail (Carleton), Mohamed Gomaa Mohamed, Paul St-Aubin (Polytechnique Montréal), Luis Miranda-Moreno, Sohail Zangenehpour (McGill)
- 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 prediction methods for surrogate safety analysis. In *Transportation Research Board Annual Meeting Compendium of Papers*. 13-4647. Accepted for publication in Transportation Research Record: Journal of the Transportation Research Board.


presented at the 2008 Transportation Research Board Annual Meeting.


A surrogate safety analysis at protected freeway ramps using cross-sectional and before-after video data.

In *Transportation Research Board Annual Meeting Compendium of Papers*. 12-2955.
