Automated Surrogate Road Safety Analysis
CIISE Distinguished Seminar Series, Concordia University

Nicolas Saunier
nicolas.saunier@polymtl.ca

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Outline

Motivation

Probabilistic Framework for Automated Road Safety Analysis

Experimental Results using Video Data

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>
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<tr>
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<td>9.7</td>
</tr>
<tr>
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<td>7.0</td>
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<tr>
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<td>Diarrhoeal diseases</td>
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<td>HIV/AIDS</td>
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<td>7</td>
<td>Tuberculosis</td>
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</tr>
<tr>
<td>8</td>
<td>Trachea, bronchus, lung cancers</td>
<td>2.3</td>
</tr>
<tr>
<td>9</td>
<td>Road traffic injuries</td>
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</tr>
<tr>
<td>10</td>
<td>Prematurity and low birth weight</td>
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<td>Neonatal infections and other</td>
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<td>Diabetes mellitus</td>
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<td>Self-inflicted injuries</td>
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<td>1.4</td>
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Safety

- Safety is characterized by the absence of accidents.
- The term “accident” is usually avoided in order to highlight their predictable and preventable nature: collision or crashes are preferred.
- Safety is defined as the number of collisions expected to occur at a given location per unit of time, where “expected” refers to “the average in the long run if it were possible to freeze all prevailing conditions that affect safety.” [Hauer et al., 1988]
The Risk of Collision

Would you consider that the risk associated with rolling a dice and playing the Russian roulette are the same?
The Risk of Collision

Would you consider that the risk associated with rolling a dice and playing the Russian roulette are the same? Would you consider that the risk associated with a collision involving two cars, or a car and a pedestrian are the same (other things being equal)?
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The concept of risk associated with an event involves two dimensions:

- the probability of the event
- the consequences of the event

In mathematical terms, the risk corresponds to the expected value of a random variable measuring the consequence of the event.
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. Traditional road safety analysis relying on historical collision data
   - “Accident analysis is a desk tool, not a field tool” (C. Hydén)

2. Vehicular accident reconstruction providing in-depth collision data
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   - “Accident analysis is a desk tool, not a field tool” (C. Hydén)
2. Vehicular accident reconstruction providing in-depth collision data
3. Real-time collision-prone location identification
4. Naturalistic driving studies
5. Surrogate safety analysis
Historical collision data is collected after the occurrence of the collision. It suffers from the following issues [Ismail, 2010]

1. difficult attribution of collisions to a cause
   - reports are skewed towards the attribution of responsibility, not the search for the causes that led to a collision
Shortcomings of Traditional Road Safety Analysis

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2. **small** data quantity
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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
Traditional Road Safety Analysis is** Reactive**

- The following **paradox** ensues: safety analysts need to wait for accidents to happen in order to prevent them.
Traditional Road Safety Analysis is Reactive

- The following paradox ensues: safety analysts need to wait for accidents to happen in order to prevent them.
- There is a need for proactive methods for road safety analysis, i.e., that do not rely on the occurrence of collisions. The recent new keyword is surrogate safety analysis.
Surrogate Measures of Safety

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- bring complementary information
- are related to traffic events that are more frequent than collisions and can be observed in the field
- are correlated to collisions, logically and statistically
Traffic Conflicts

- Traffic conflicts have received the most attention since their first conceptualization in 1968 in the General Motors Research Laboratories [Perkins and Harris, 1968]

- The accepted definition of 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]

- Traffic Conflict Techniques (TCT)
  - A TCT is a method for traffic safety estimation based on the observation of traffic conflicts [Laureshyn, 2010]
  - The basic hypothesis of TCTs is that accidents and conflicts originate from the same type of processes in traffic and a relation between them can be found
  - TCTs involve observing and evaluating the frequency and severity of traffic conflicts at a given road location by a team of trained observers
A Traffic Conflict
An interaction is a situation in which two road users are close enough.

Conflict severity = probability of collision = position in the safety hierarchy.
Limitations of Traffic Conflict Techniques

- Limits caused by the *manual* data collection process
  - *Costly* manual/semi-automated collection
  - Reliability and subjectivity of human observers
- Mixed validation results in the literature
Motivation

- Need for **automated** tools to address the shortcomings of reactive diagnosis methods and traffic conflict techniques
- Better understand **collision processes and similarities** between interactions with and without a collision for improved safety diagnosis
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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”
Rethinking the Collision Course

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- For two interacting road users, many chains of events may lead to a collision
Rethinking the Collision Course

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- 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): constant velocity, normal adaptation, etc.
  - 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:

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

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

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

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

Applications

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

Traffic conflicts, exposure and severity measures, interacting behavior

Interactions
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)
The Kentucky Dataset

- Video recordings kept for a few seconds before and after the sound-based automatic detection of an interaction of interest
  - 229 traffic conflicts
  - 101 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

[Saunier et al., 2010]
Severity Indicators

Side conflict
Severity Indicators

Side conflict
Severity Indicators

Parallel conflict
Severity Indicators

Side collision
Severity Indicators

Side collision
Severity Indicators

Parallel collision
Distribution of Indicators and Aggregation

**Maximum Collision Probability**

<table>
<thead>
<tr>
<th>Collision Probability</th>
<th>Traffic Conflicts</th>
</tr>
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<tbody>
<tr>
<td>0.1</td>
<td>140</td>
</tr>
<tr>
<td>0.2</td>
<td>120</td>
</tr>
<tr>
<td>0.3</td>
<td>80</td>
</tr>
<tr>
<td>0.4</td>
<td>60</td>
</tr>
<tr>
<td>0.5</td>
<td>40</td>
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<tr>
<td>0.6</td>
<td>20</td>
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<tr>
<td>0.7</td>
<td>10</td>
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<tr>
<td>0.8</td>
<td>5</td>
</tr>
<tr>
<td>0.9</td>
<td>5</td>
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<tr>
<td>1.0</td>
<td>0</td>
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**Minimum TTC**

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<thead>
<tr>
<th>TTC (second)</th>
<th>Traffic Conflicts</th>
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<tr>
<td>0.0</td>
<td>60</td>
</tr>
<tr>
<td>0.5</td>
<td>50</td>
</tr>
<tr>
<td>1.0</td>
<td>40</td>
</tr>
<tr>
<td>1.5</td>
<td>30</td>
</tr>
<tr>
<td>2.0</td>
<td>20</td>
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<tr>
<td>2.5</td>
<td>10</td>
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<td>3.0</td>
<td>5</td>
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<td>3.5</td>
<td>5</td>
</tr>
<tr>
<td>4.0</td>
<td>0</td>
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<tr>
<td>4.5</td>
<td>0</td>
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**Collisions**

<table>
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<tr>
<th>TTC (second)</th>
<th>Collisions</th>
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<tr>
<td>0.0</td>
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<tr>
<td>0.5</td>
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<td>1.0</td>
<td>20</td>
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<td>1.5</td>
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<td>4.0</td>
<td>0</td>
</tr>
<tr>
<td>4.5</td>
<td>0</td>
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Spatial Distribution of the Collision Points

Traffic Conflicts

0
8
16
24
32
40
48
56
64
72
Spatial Distribution of the Collision Points
Study Before and After the Introduction of a Scramble Phase

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

Histogram of Before-and-After TTC

TTC in seconds

Frequency of traffic events

TTC Before

TTC After

Histogram of Before-and-After DST

DST max in seconds

Histogram of Before-and-After PET

|PET| in seconds

Histogram of Before-and-After GT

GT in seconds

|PET| Before

|PET| After

GT Before

GT After

|GT| Before

|GT| After
Before and After Distribution of the Collision Points
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., 2013]

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

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

Untreated site (no lane marking)  [St-Aubin et al., 2013]
Clustering Severity Indicators

Cluster 1 - 23.3% (28/120)

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)

[Saunier and Mohamed, 2014]
Clustering Severity Indicators

Clustering Severity Indicators

Cluster 1 - 19.4%(13/67)
Cluster 2 - 38.5%(55/143)
Cluster 3 - 33.3%(3/9)
Cluster 4 - 5.0%(1/20)

[Saunier and Mohamed, 2014]
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Mohamed and Saunier, 2013
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  - is TTC sufficient to measure interaction severity, or probability of collision?

[Mohamed and Saunier, 2013]
Conclusion

- Surogate 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:
  - is TTC sufficient to measure interaction severity, or probability of collision?
  - an extra dimension seems conceptually necessary to measure the ability of road users to avoid the collision, e.g. DST (a probability of unsuccessful evasive action) [Mohamed and Saunier, 2013]
Ongoing work: roundabouts, vulnerable road users (cycle paths, bus stops and pedestrians)

Need for large amounts of data for the understanding and modelling of collision processes

Video-based trajectory data collection, naturalistic driving studies (SHRP2)

Need for data mining and visualization techniques for safety analysis

Validation of proactive methods for road safety analysis

Open Science: data sharing and open source code

http://nicolas.saunier.confins.net, Traffic Intelligence

Public traffic video dataset for benchmarks and TRB 2014 workshop [Saunier et al., 2014]
Perspectives

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- Improve the tools for automated data collection (computer vision)

[Saunier et al., 2014]
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Questions?


