Automated Proactive Road Safety Analysis

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ÉCOLE POLYTECHNIQUE
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Outline

Motivation

Probabilistic Framework for Automated Road Safety Analysis

Experimental Results using Video Data

Investigating Collision Factors Using Microscopic 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>
<td>12.2</td>
</tr>
<tr>
<td>2</td>
<td>Cerebrovascular disease</td>
<td>9.7</td>
</tr>
<tr>
<td>3</td>
<td>Lower respiratory infections</td>
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</tr>
<tr>
<td>4</td>
<td>Chronic obstructive pulmonary disease</td>
<td>5.1</td>
</tr>
<tr>
<td>5</td>
<td>Diarrhoeal diseases</td>
<td>3.6</td>
</tr>
<tr>
<td>6</td>
<td>HIV/AIDS</td>
<td>3.5</td>
</tr>
<tr>
<td>7</td>
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<td>2.5</td>
</tr>
<tr>
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<td>Trachea, bronchus, lung cancers</td>
<td>2.3</td>
</tr>
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<td>9</td>
<td>Road traffic injuries</td>
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</tr>
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<td>10</td>
<td>Prematurity and low birth weight</td>
<td>2.0</td>
</tr>
<tr>
<td>11</td>
<td>Neonatal infections and other</td>
<td>1.9</td>
</tr>
<tr>
<td>12</td>
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</tr>
<tr>
<td>13</td>
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</tr>
<tr>
<td>14</td>
<td>Hypertensive heart disease</td>
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</tr>
<tr>
<td>15</td>
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<td>1.5</td>
</tr>
<tr>
<td>16</td>
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<td>1.4</td>
</tr>
<tr>
<td>17</td>
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<tr>
<td>18</td>
<td>Cirrhosis of the liver</td>
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Road Safety Analysis

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  - Insufficient data to understand the processes that lead to collisions
  - Reactive approach
- Need for proactive approaches and surrogate safety measures that do not depend on the occurrence of collisions
Surrogate Safety Measures

- Research on surrogate safety measures that
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[Amundsen and Hydén, 1977]
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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]
Automated Methods

• Need for more **microscopic** traffic data
• **Surrogate** safety measures, e.g. in traffic conflict studies, are collected with various levels of automation
• The main bottleneck for proactive methods is that data is still mostly collected **manually**
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The Safety/Severity Hierarchy

Accidents

Various severity measures

Serious Conflicts
Slight Conflicts
Potential Conflicts
Undisturbed passages
The Collision Course

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- 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
Movement Prediction

- Learn road users’ motion patterns (including frequencies), represented by actual trajectories called prototypes
- Match observed trajectories to prototypes and extrapolate

[Saunier et al., 2007, Saunier and Sayed, 2008]
A Simple Example
Collision Points

Using of a finite set of extrapolation hypotheses, enumerate the collision points $CP_n$. Severity indicators can then be computed:

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

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

[Saunier et al., 2010]
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Motion Pattern Learning

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<thead>
<tr>
<th>Traffic Conflict Dataset, Vancouver</th>
<th>Reggio Calabria, Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td>58 prototype trajectories</td>
<td>58 prototype trajectories</td>
</tr>
<tr>
<td>(2941 trajectories)</td>
<td>(138009 trajectories)</td>
</tr>
</tbody>
</table>
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
- Calibration done using the tool developed by Karim Ismail at UBC [Ismail et al., 2010b]
Severity Indicators

Side conflict
Severity Indicators

![Graph showing collision probability over time]

Time (second)
5.0 5.5 6.0 6.5
0.00 0.05 0.10 0.15 0.20 0.25 0.30
Collision Probability

TTC (second)
5.0 5.5 6.0 6.5
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
Time (second)
5.0 5.5 6.0 6.5

Side conflict
Severity Indicators

Parallel conflict
Severity Indicators

Side collision
Severity Indicators

Side collision
Severity Indicators

Parallel collision
Distribution of Indicators

Maximum Collision Probability

Minimum TTC
Spatial Distribution of the Collision Points

Traffic Conflicts
Spatial Distribution of the Collision Points
Study Before and After the Introduction of a Scramble Phase

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

Histogram of Before-and-After TTC

- TTC Before
- TTC After

Histogram of Before-and-After DST

- DST Before
- DST After

Histogram of Before-and-After PET

- PET Before
- PET After

Histogram of Before-and-After GT

- GT Before
- GT After

TTC Before vs. TTC After

Distribution of Severity Indicators

Experimental Results
Before and After Distribution of the Collision Points
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- Understand collision processes by studying the similarities of interactions with and without a collision (conflicts)

[Saunier et al., 2011]
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- 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 [Davis et al., 2008]

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  - Importance for surrogate safety measures: what interactions without a collision may be used as surrogates for collisions?

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  - Importance for surrogate safety measures: what interactions without a collision may be used as surrogates for collisions?
- Use of **data mining** techniques (k-means and hierarchical agglomerative clustering method) to cluster the data

[Saunier et al., 2011]
## 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, opposite direction, side</td>
</tr>
<tr>
<td><em>Interaction outcome</em></td>
<td>conflict, collision</td>
</tr>
</tbody>
</table>
### Description of Interactions (continued)

<table>
<thead>
<tr>
<th>Numerical attributes</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Road user type</strong></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>bike</td>
<td>number of road users</td>
</tr>
<tr>
<td>pedestrian</td>
<td>number of road users</td>
</tr>
<tr>
<td><strong>Type of evasive action</strong></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><strong>3 attributes from</strong> $\Delta v$</td>
<td>km/h</td>
</tr>
<tr>
<td><strong>6 values from</strong> $s$</td>
<td>km/h</td>
</tr>
</tbody>
</table>
Distribution of Speed Attributes

Norm of the velocity difference

Speed

Collision
Conflict

DeltaVmin
DeltaV
DeltaVmax

Smin1
Smin2
S1
S2
Smax1
Smax2

Speed (km/h)

DeltaV (km/h)

Norm of the velocity difference
Collision
Conflict
3 Clusters

Interaction outcome

Cluster 1
Cluster 2
Cluster 3

Number of interactions

Collision
Conflict

Number of interactions
3 Clusters: Speed Attributes
3 Clusters: Interaction Category

Interaction category

Side straight
Same dir. chang.
Same dir. rear
Same dir. turn R
Same dir. turn L

Number of interactions

Cluster 1
Cluster 2
Cluster 3
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- Tools and framework for **automated** road safety analysis using video sensors
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- **Large** amounts of data: data mining and visualization for safety analysis

http://nicolas.saunier.confins.net
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- Future work:

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- Large amounts of data: data mining and visualization for safety analysis
- Future work:
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  - Validation of proactive methods for road safety analysis
  - Understanding and modelling of collision processes: collect more data
- Need for more open science: data and code sharing
  http://nicolas.saunier.confins.net
Collaboration with

- Clark Lim and Tarek Sayed (University of British Columbia)
- Karim Ismail (Carleton University)
- Nadia Mourji, Bruno Agard (École Polytechnique de Montréal)
Questions ?


