Automated Proactive Road Safety Analysis

Transportation Research At McGill Seminar

Nicolas Saunier
nicolas.saunier@polymtl.ca

ÉCOLE
POLYTECHNIQUE
MONTRÉAL

November 25^{th} 2010

Outline

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

TOTAL 2004

RANK	LEADING CAUSE	%
1	Ischaemic heart disease	12.2
2	Cerebrovascular disease	9.7
3	Lower respiratory infections	7.0
4	Chronic obstructive pulmonary disease	5.1
5	Diarrhoeal diseases	3.6
6	HIV/AIDS	3.5
7	Tuberculosis	2.5
8	Trachea, bronchus, lung cancers	2.3
9	Road traffic injuries	2.2
10	Prematurity and low birth weight	2.0
11	Neonatal infections and other	1.9
12	Diabetes mellitus	1.9
13	Malaria	1.7
14	Hypertensive heart disease	1.7
15	Birth asphyxia and birth trauma	1.5
16	Self-inflicted injuries	1.4
17	Stomach cancer	1.4
18	Cirrhosis of the liver	1.3
19	Nephritis and nephrosis	1.3
20	Colon and rectum cancers	1.1

TOTAL 2030

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10	HIV/AIDS	2.0
11	Nephritis and nephrosis	1.9
12	Self-inflicted injuries	1.9
13	Liver cancer	1.7
14	Colon and rectum cancer	1.7
15	Oesophagus cancer	1.5
16	Violence	1.4
17	Alzheimer and other dementias	1.4
18	Cirrhosis of the liver	1.3
19	Breast cancer	1.3
20	Tuberculosis	1.1

Source: World health statistics 2008 (http://www.who.int/whosis/whostat/2008/en/index.html)

Road Safety Analysis

- Limits of the traditional approach based on historical collision data:
  - problems of availability and quality
  - insufficient data to understand the processes that lead to collisions
  - reactive approach
  - pedestrians: issues are made more accute by the rarity of collisions and the lack of data (exposure)
- Need for proactive approaches and surrogate safety measures that do not depend on the occurrence of collisions

Surrogate Safety Measures

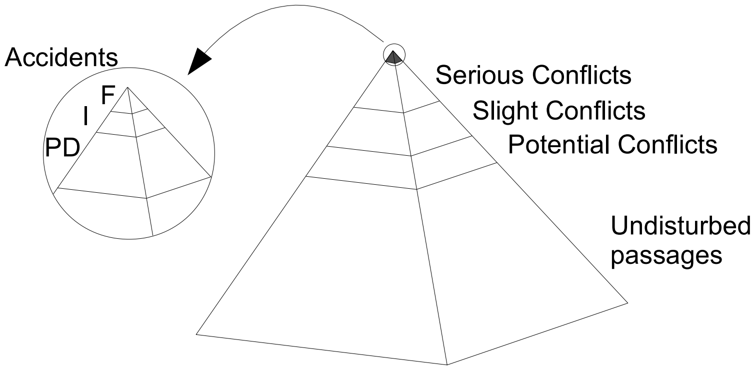
- Research on surrogate safety measures that
  - bring complementary information
  - are related to traffic events that are more frequent than collisions and can be observed in the field
  - are correlated to collisions, logically and statistically

Traffic Conflicts

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
- Limits caused by the data collection process (human observers in the field)
  - cost
  - intra- and inter-observer variability
- Mixed validation results

The Safety/Severity Hierarchy



Various severity measures

Motivation

Need for automated tools to address the shortcomings of reactive diagnosis methods and traffic conflict techniques

The Collision Course

> *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]*

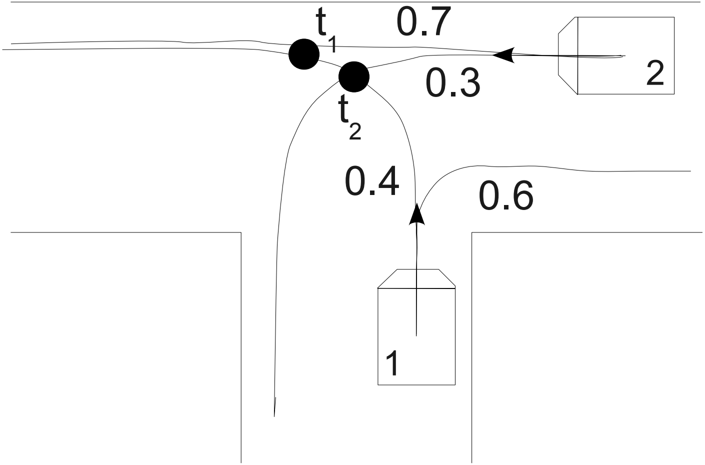
The extrapolation hypotheses must be specified.

Rethinking the Collision Course

- 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
  - 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, the collision points CP_n are enumerated
- The probability of collision si computed by summing the probabilities of reaching each potential collision point

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

- The expected Time To Collision is also computed (if there is at least one collision point, i.e. $P(Collision(U_i, U_j)) > 0$)

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

[Saunier et al., 2010]

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

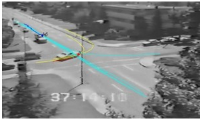
+

Camera Calibration

+

Labeled Images for Road User Type

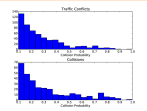
Road User Trajectories



Interactions

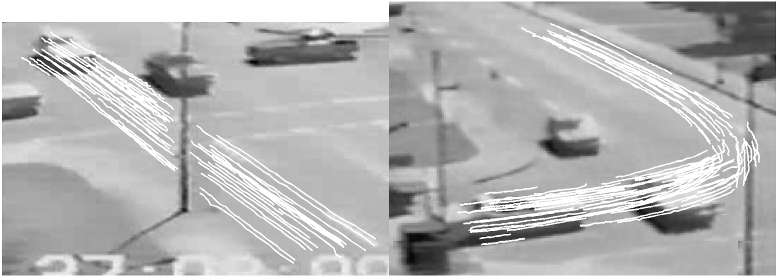
Applications

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



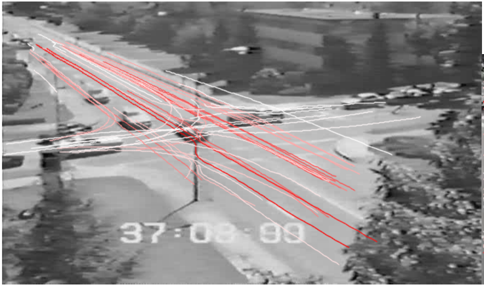
Traffic conflicts, exposure and severity measures, interacting behavior

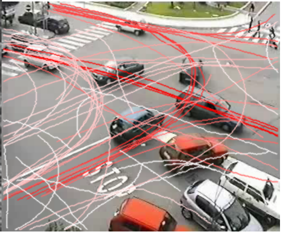
Feature-based Road User Tracking in Video Data



Good enough for safety analysis and other applications, including the study of pedestrians and pedestrian-vehicle interactions [Saunier and Sayed, 2006]

Motion Pattern Learning



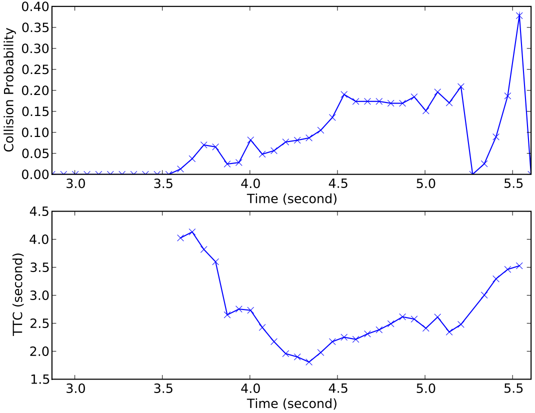


Traffic Conflict Dataset, Vancouver	Reggio Calabria, Italy
58 prototype trajectories (2941 trajectories)	58 prototype trajectories (138009 trajectories)

The Kentucky Dataset

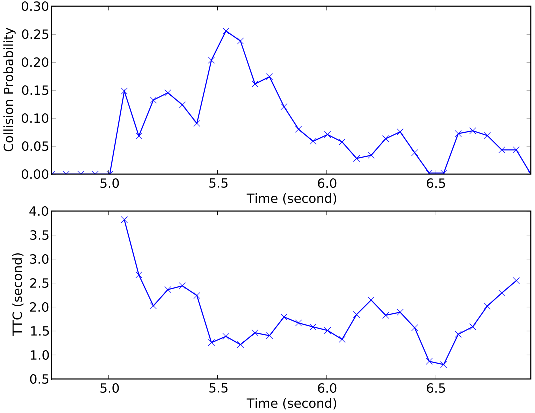
- Video recordings kept for a few seconds before and after the sound-based automatic detection of an interaction of interest
  - 229 traffic conflicts
  - 101 collisions
  - The existence of an interaction or its severity is not always obvious
  - The interactions recorded in this dataset involve only motorized vehicles
  - Limited quality of the video data: resolution, compression, weather and lighting conditions
- Calibration done using the tool developed by Karim Ismail at UBC [Ismail et al., 2010b]

Severity Indicators



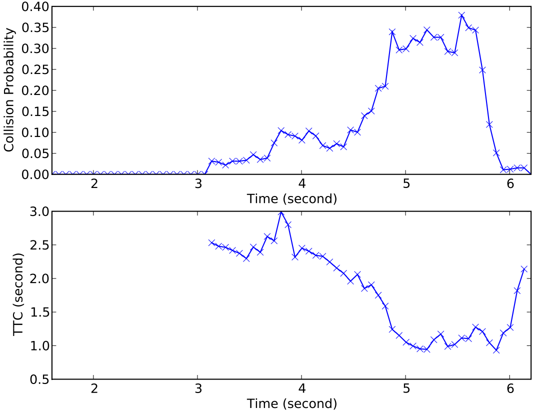
Side conflict

Severity Indicators



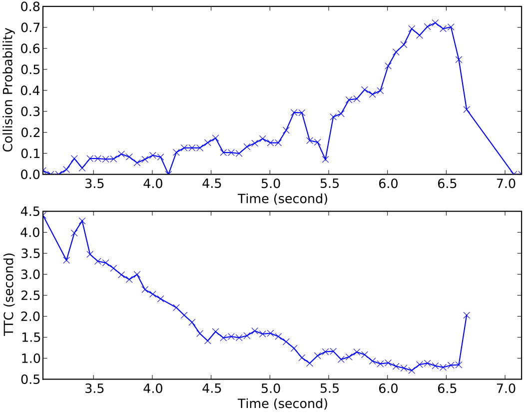
Side conflict

Severity Indicators



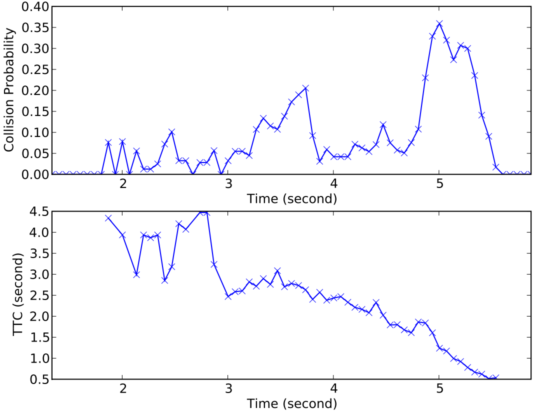
Parallel conflict

Severity Indicators



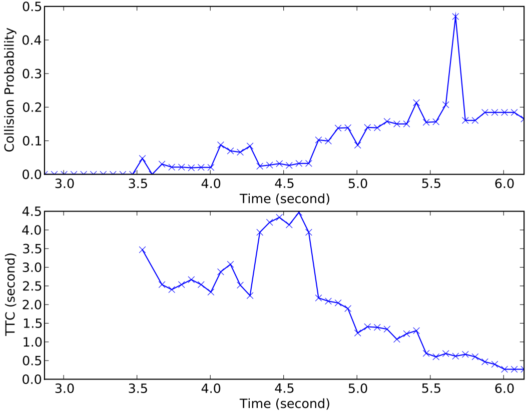
Side collision

Severity Indicators



Side collision

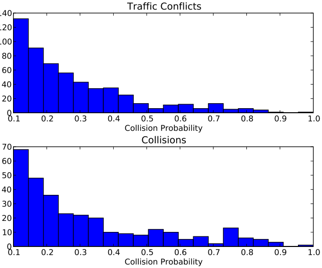
Severity Indicators



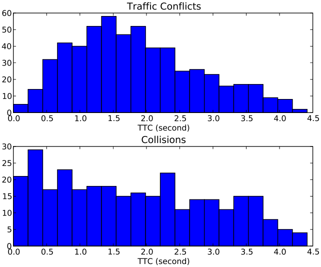
Parallel collision

Distribution of Indicators

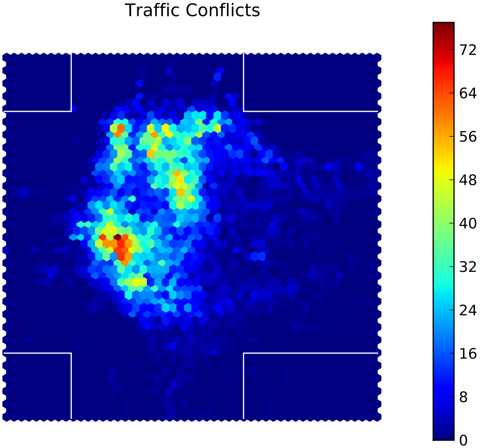
Maximum Collision Probability



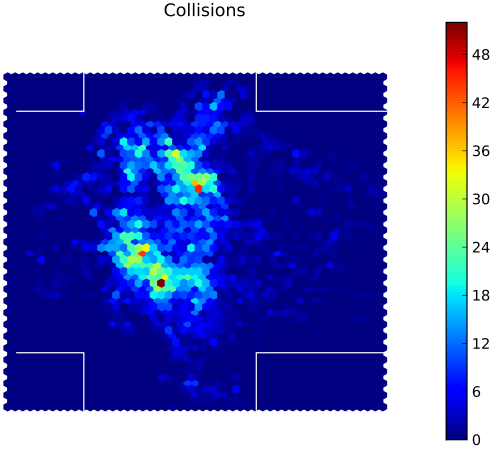
Minimum TTC



Spatial Distribution of the Collision Points



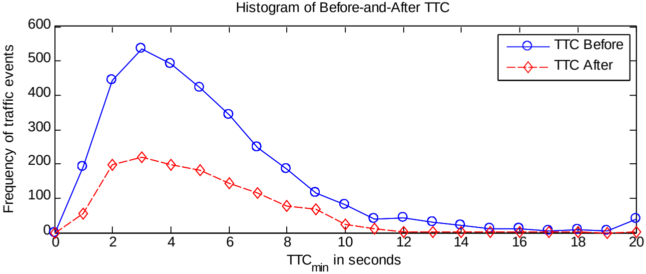
Spatial Distribution of the Collision Points



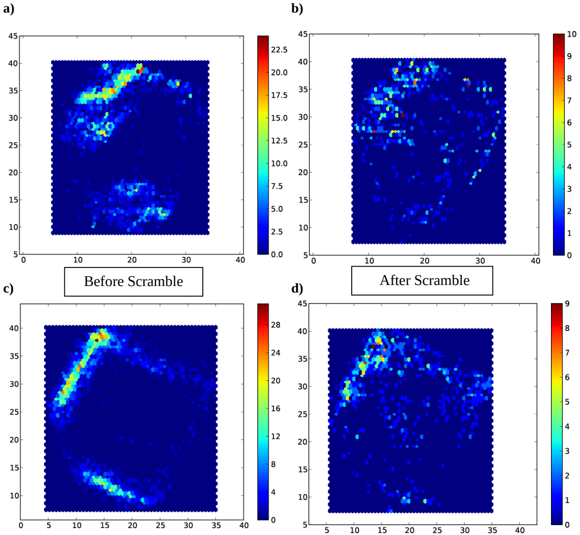
Study Before and After the Introduction of a Scramble Phase

Data collected in Oakland, CA [Ismail et al., 2010a]

Distribution of Severity Indicators



Before and After Distribution of the Collision Points



Objectives

- Understand collision processes by studying the similarities of interactions with and without a collision (conflicts)
- 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]
  - 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]

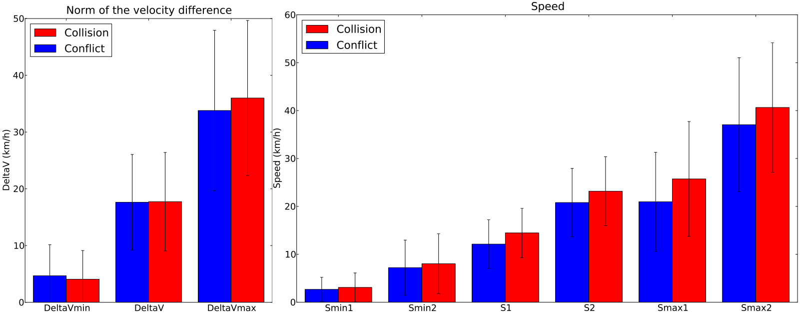
Description of Interactions

Categorical attributes	**Values**
Type of day	weekday, week end
Lighting condition	daytime, twilight, nighttime
Weather condition	normal, rain, snow
Interaction category	same direction (turning left and right, rear-end, lane change), opposite direction (turning left and right, head-on), side (turning left and right, straight)
Interaction outcome	conflict, collision

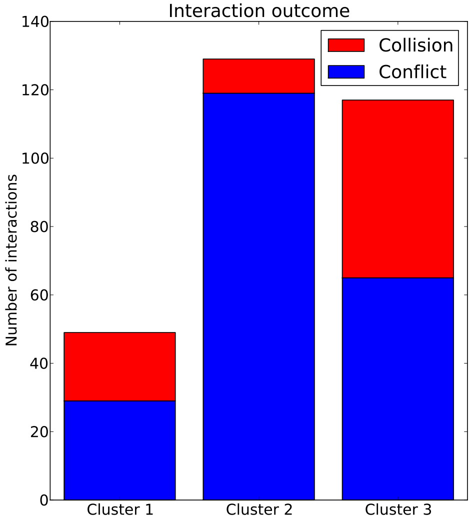
Description of Interactions

Numerical attributes	**Units**
Road user type	
passenger car	number of road users
van, 4x4, SUV	number of road users
bus	number of road users
truck (all sizes)	number of road users
motorcycle	number of road users
bike	number of road users
pedestrian	number of road users
Type of evasive action	
No evasive action	number of evasive actions
Braking	number of evasive actions
Swerving	number of evasive actions
Acceleration	number of evasive actions
3 attributes from Δv	km/h
6 values from s	km/h

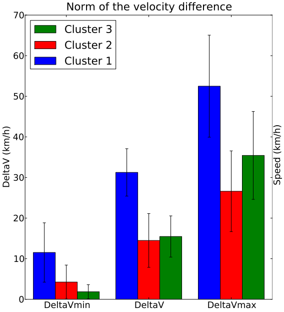
Distribution of Speed Attributes

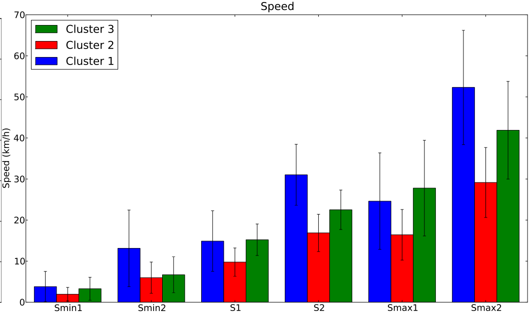


3 Clusters

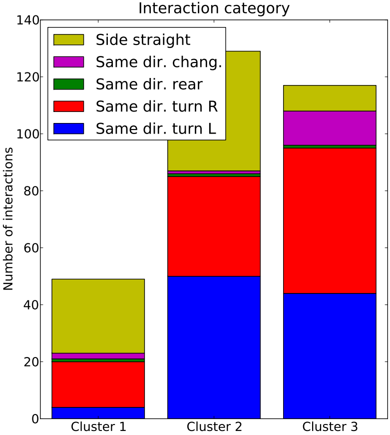

Interaction outcome
Collision
Conflict
Number of interactions
0
20
40
60
80
100
120
140
Cluster 1
Cluster 2
Cluster 3

Clusters: Speed Attributes





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

Conclusion

- Tools and framework for automated road safety analysis using video sensors
- Large amounts of data: data mining and visualization for safety analysis
- Future work:
  - Still more work on data collection techniques (computer vision)
  - 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?

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