# Automated Surrogate Road Safety Analysis

## CIISE Distinguished Seminar Series, Concordia University

Nicolas Saunier
nicolas.saunier@polymtl.ca

POLYTECHNIQUE MONTRÉAL
WORLD-CLASS ENGINEERING

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# Outline

- Motivation
- Probabilistic Framework for Automated Road Safety Analysis
- Experimental Results using Video Data
- Conclusion

# 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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| 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)

# 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]

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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)?
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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2. Vehicular accident reconstruction providing in-depth collision data
3. Real-time collision-prone location identification
4. Naturalistic driving studies
5. Surrogate safety analysis

# Shortcomings of Traditional Road 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

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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
2. small data quantity
3. limited quality of the data reconstituted after the event, with a bias towards more damaging collisions

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- 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

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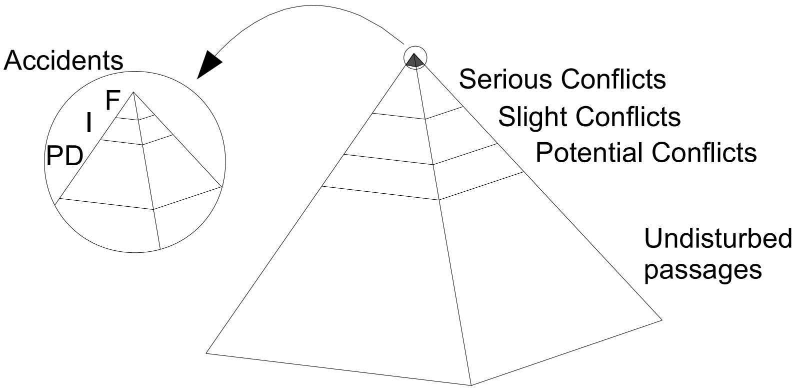
- are related to traffic events that are more frequent than collisions and can be observed in the field
- are correlated to collisions, logically and statistically

# 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

# The Safety Hierarchy




- 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

# Outline

# Rethinking the Collision Course

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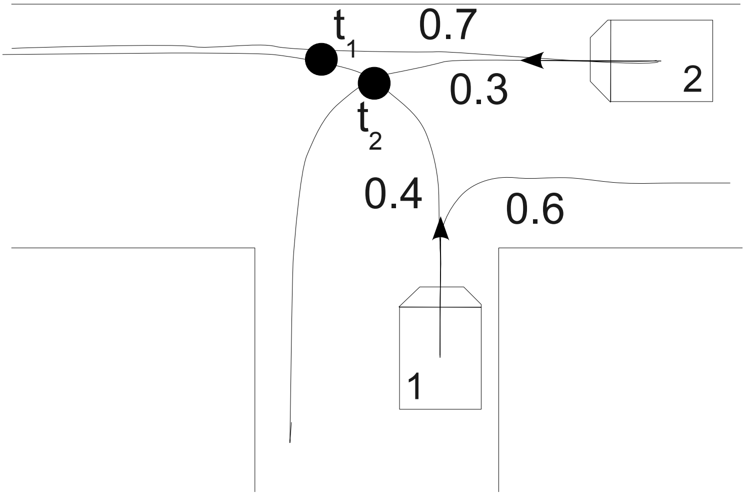
- It is possible to estimate the probability of collision if one can predict the road users’ future positions
  - The motion prediction method must be specified

# 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:

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

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

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

[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

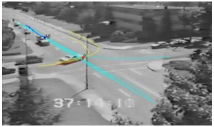
+

Camera Calibration

+

Labeled Images for Road User Type

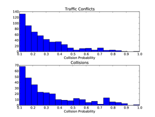
Road User Trajectories



Interactions

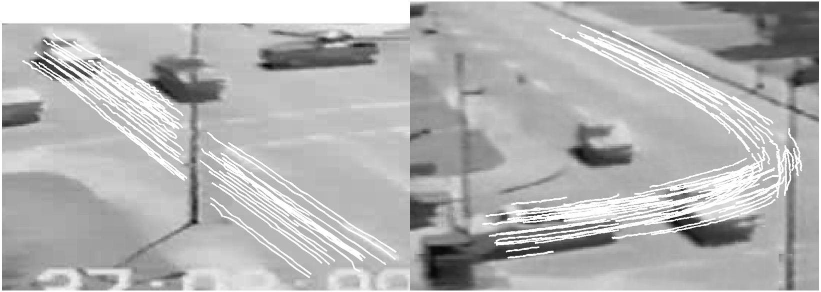
## Applications

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



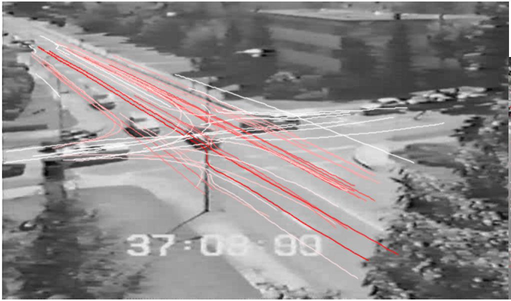

Traffic conflicts, exposure and severity measures, interacting behavior

# Feature-based Road User Tracking in Video Data



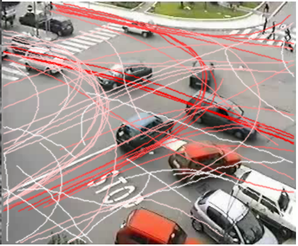
Good enough for safety analysis and other applications, including the study of pedestrians and pedestrian-vehicle interactions [Saunier and Sayed, 2006]

# Motion Pattern Learning



Traffic Conflict Dataset, Vancouver

58 prototype trajectories
(2941 trajectories)



Reggio Calabria, Italy

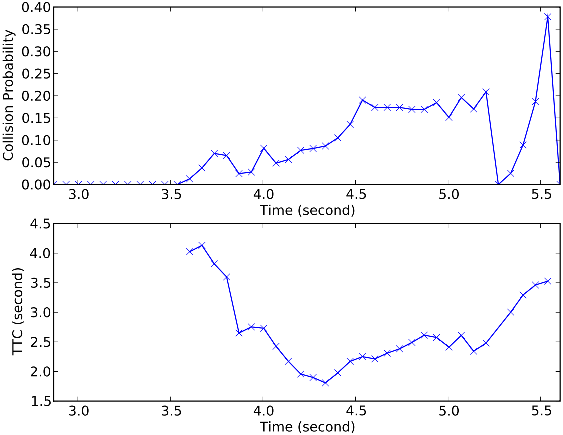
58 prototype trajectories
(138009 trajectories)

# 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

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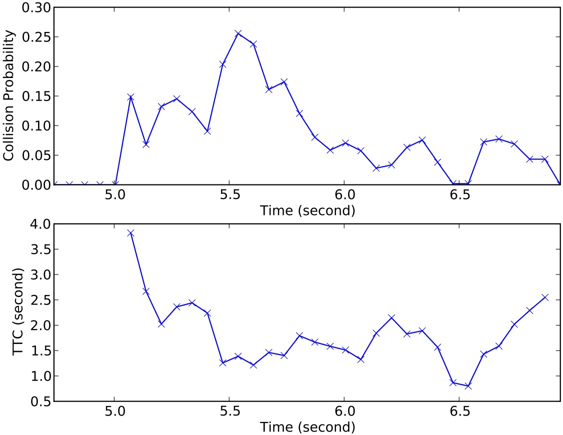


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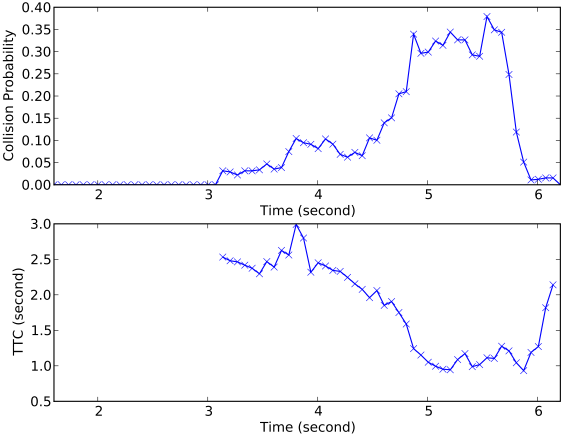


Parallel conflict

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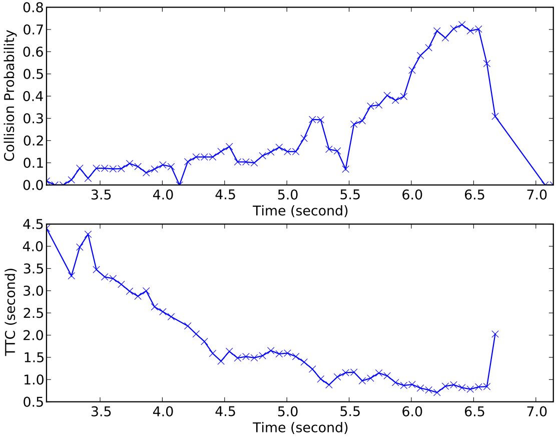
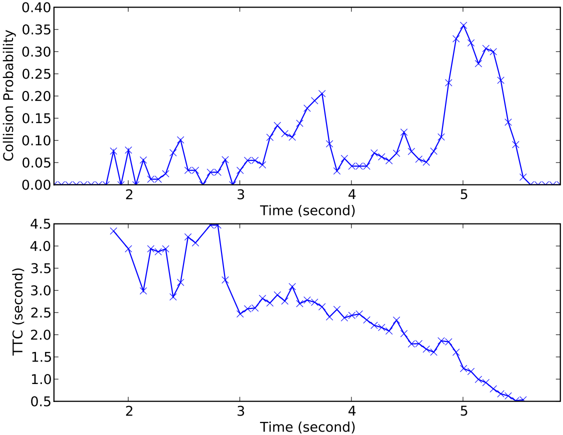



Side collision

# Severity Indicators




Side collision

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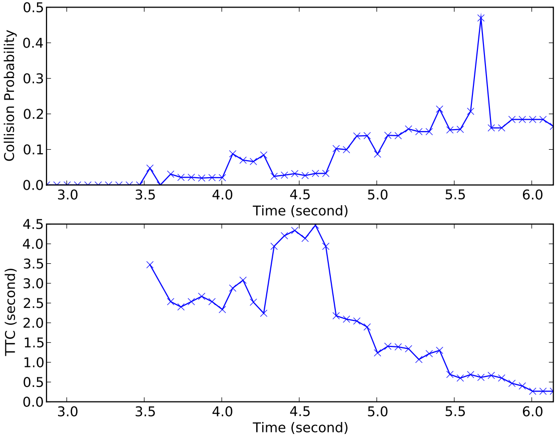
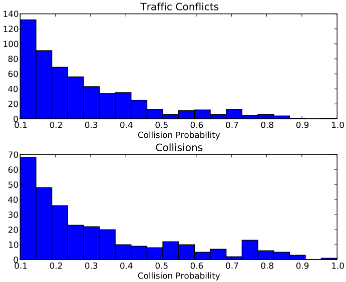


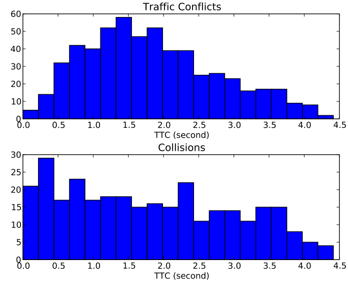

Parallel collision

# Distribution of Indicators and Agregation

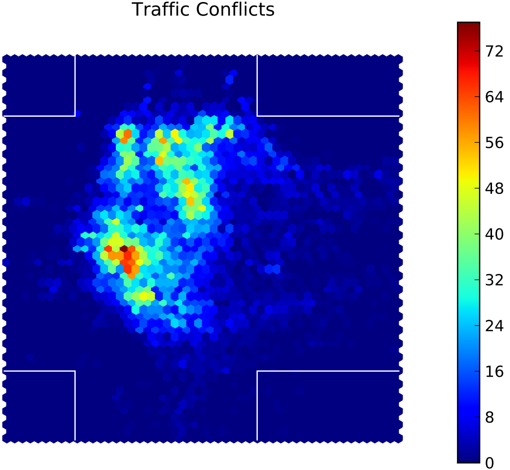
## Maximum Collision Probability




## Minimum TTC



# Spatial Distribution of the Collision Points



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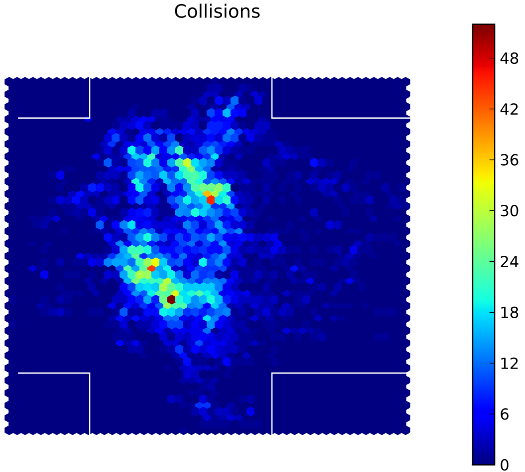
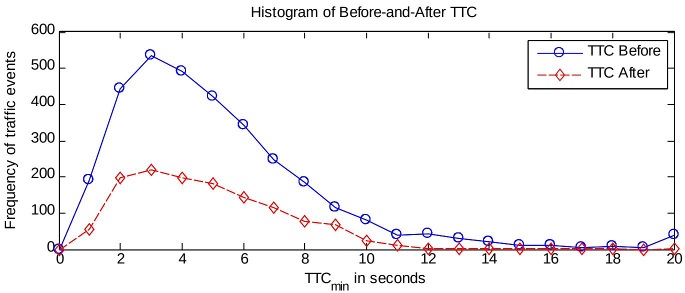


# Study Before and After the Introduction of a Scramble Phase

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

# Distribution of Severity Indicators



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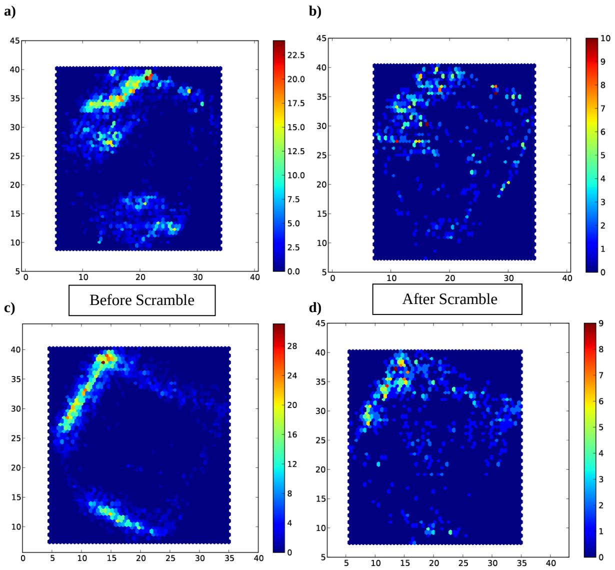


# Lane-Change Bans at Urban Highway Ramps

86

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

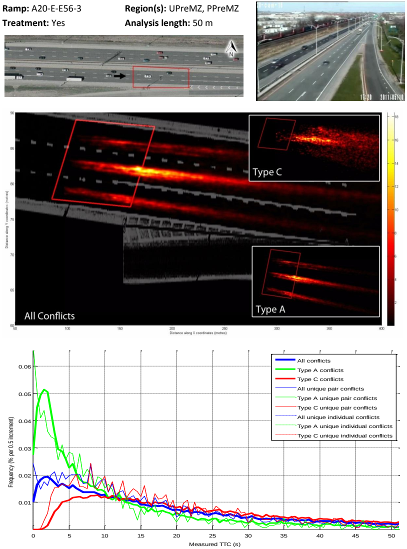



**Figure 37 – Conflict analysis Cam20-16-Dorval (Treated).**

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

# Lane-Change Bans at Urban Highway Ramps

70

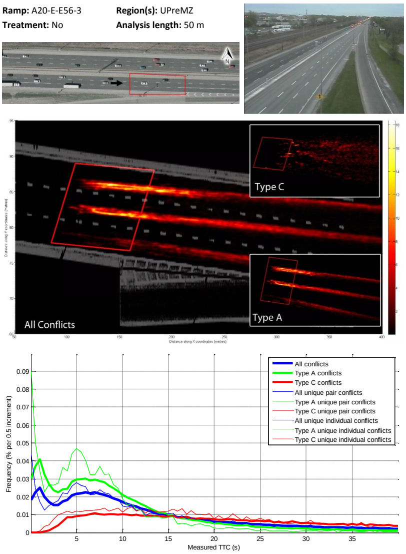
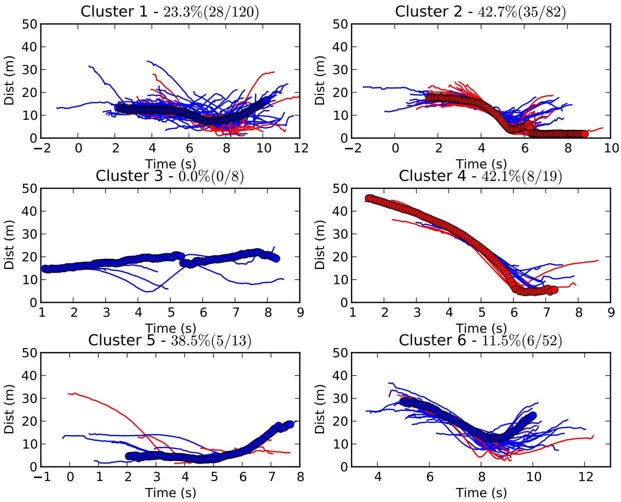



**Figure 27 – Conflict analysis Cam20-16-Dorval (Untreated).**

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

# Clustering Severity Indicators




[Saunier and Mohamed, 2014]

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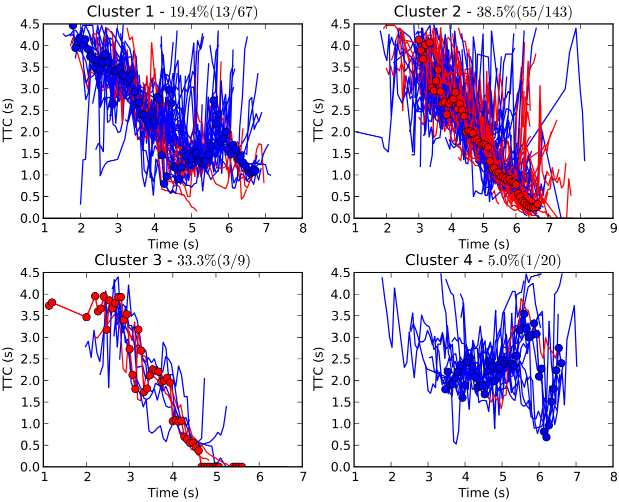


[Saunier and Mohamed, 2014]

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# Conclusion

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- 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]

# Perspectives

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  - need for data mining and visualization techniques for safety analysis

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- Validation of proactive methods for road safety analysis

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  - 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]

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Questions?

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