Automated Methods for Traffic Data Collection and Surrogate Measures of Safety

Hasselt University

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POLYTECHNIQUE MONTRÉAL
WORLD-CLASS ENGINEERING

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My Journey to Transportation

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4. 2009-: Professor in Polytechnique Montréal

Outline

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Surrogate Measures of Safety

- Looking for (complementary) measures of safety that do not require to wait for accidents to happen
- Hypothesis [Svensson and Hydén, 2006]: in the safety hierarchy, all events have a relationship to accidents (safety) that may be of different nature
- Automation using video sensors and computer vision
  - cheap hardware, open source software

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  - for all types of road users and road environments
  - generalize the concept of collision course: importance of motion prediction methods
  - improve existing indicator(s) before inventing new ones
- Better understand collision processes and the similarities between interactions with and without a collision for safety estimation

Outline

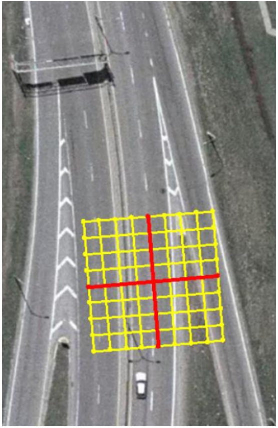
Processing Steps

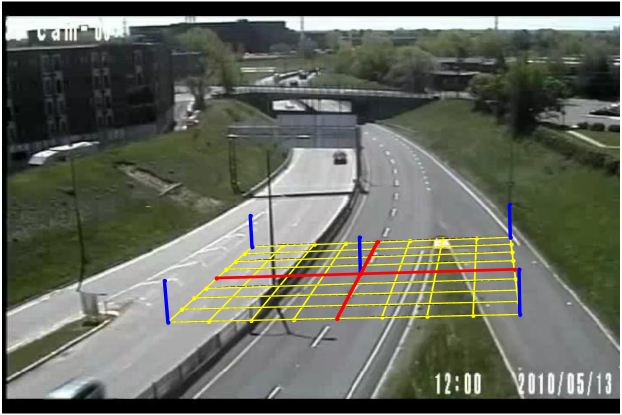
1. Video data collection
2. Data preparation
3. Moving road user detection, tracking and classification
4. Motion prediction
5. Safety indicators
6. Interpretation

Step 1: Video Data Collection

Step 2: Data Preparation

In particular, camera calibration: homography and distortion (if any)





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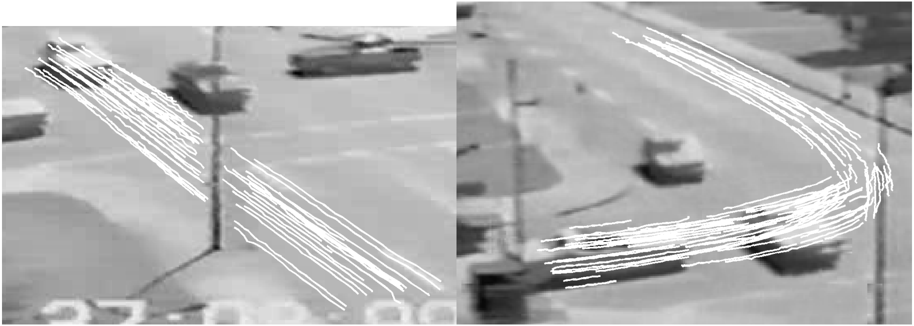
Step 3: Moving Road User Detection, Tracking and Classification



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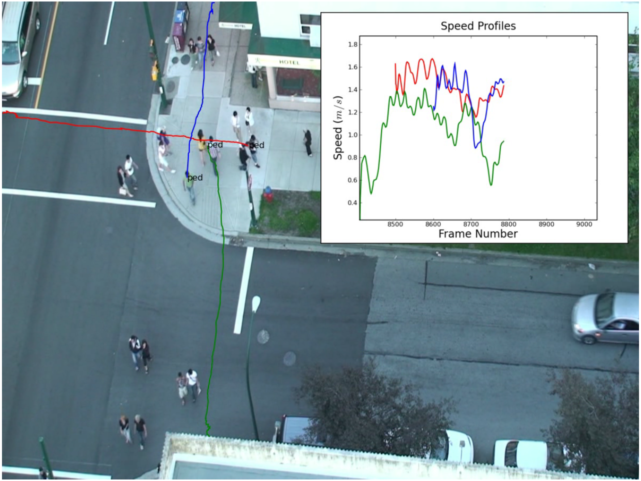

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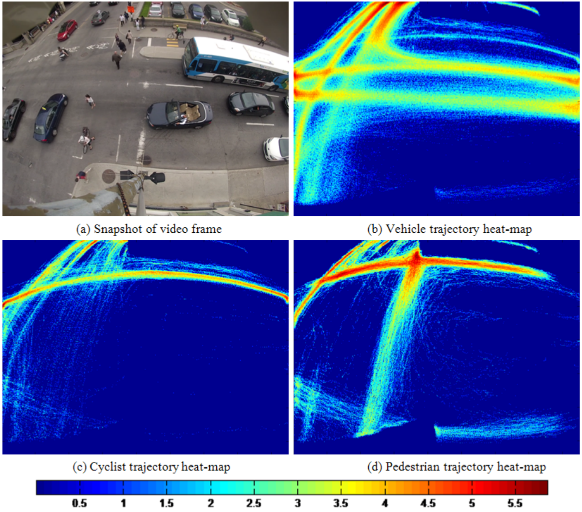


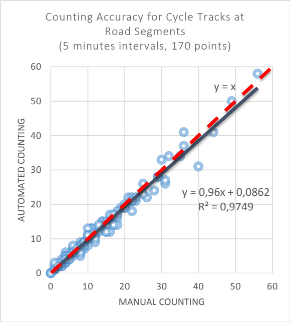
(a) Snapshot of video frame

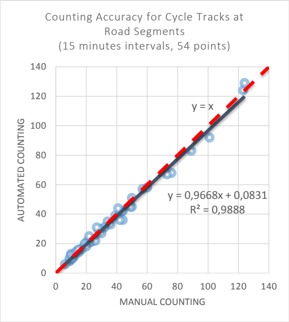
(b) Vehicle trajectory heat-map

(c) Cyclist trajectory heat-map

(d) Pedestrian trajectory heat-map

Validating Cyclist Counts in Mixed Traffic

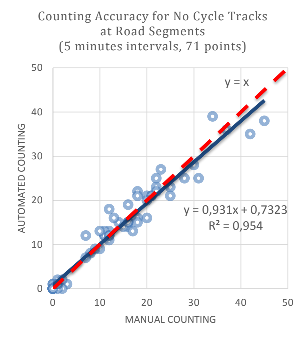


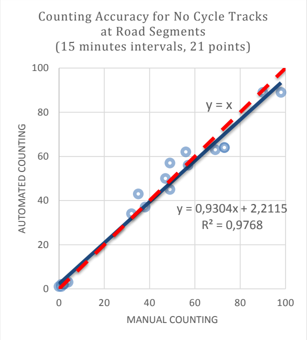


(a)

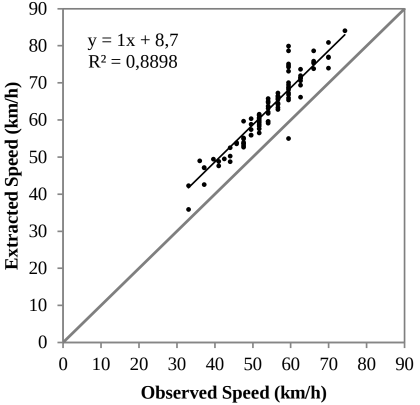
(b)

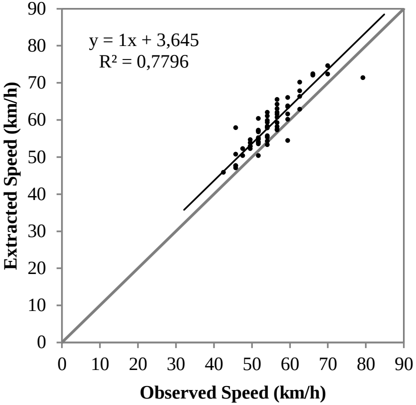
Validating Cyclist Counts in Mixed Traffic



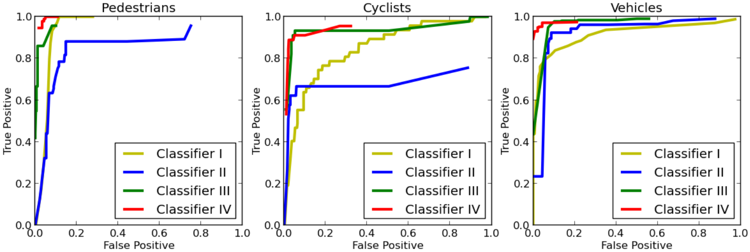


Disaggregated Vehicle Speed Validation



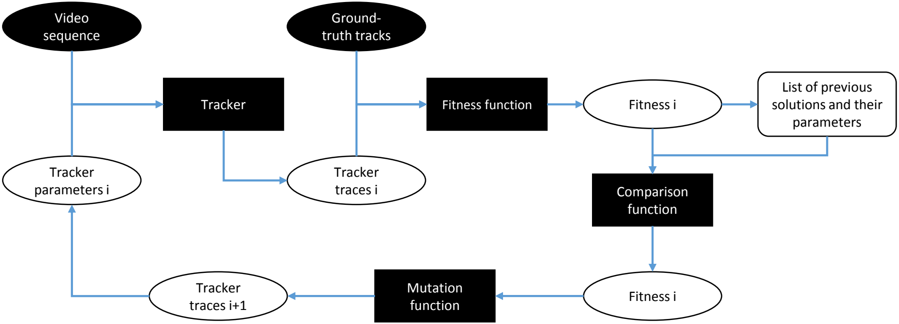


Road User Classification in Dense Mixed Traffic



ROC Curves

Tracking Parameter Optimization



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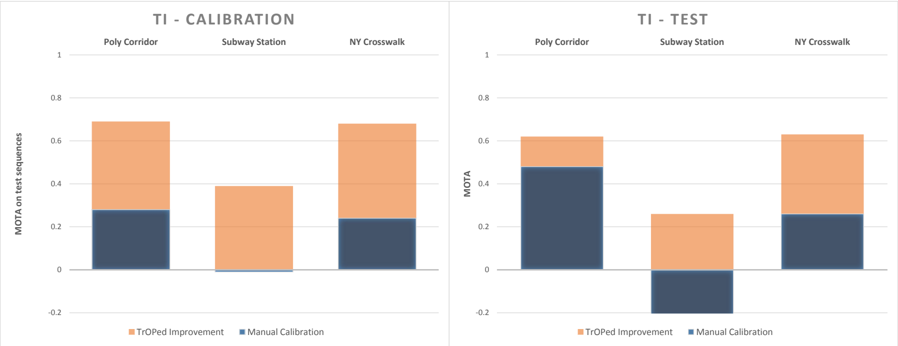


Outline

Open Science

- Principle of independent reproducibility
- Need to share data and tools used to produce the results
  - public datasets and benchmarks [Saunier et al., 2014]
  - public / open source software: adoption and contributions by researchers and practitioners
- Traffic Intelligence open source project

`https://bitbucket.org/Nicolas/trafficintelligence`

“Traffic Intelligence”

- Tools for video analysis and transportation data (a.k.a. trajectories) analysis
- Open source: MIT license (most permissive)
- Three parts
  1. “Independent” project “Trajectory Management and Analysis” (C++): trajectory I/O (SQLite), trajectory similarity/distance measures
  2. Feature-based tracking (C++): feature tracking and grouping
  3. Trajectory data analysis (Python): tracking results loading, behaviour, interaction and safety analysis

Interfaces

- It is first thought of as a library than as an end-user “click & run” tool
- It provides end-user programs: feature tracker executable, Python scripts
  - the command line is not a bug, but a feature for automation/parallelism
  - configuration files
- No (few) graphical user interface: contributions or commercial add-ons?

2-minute Rant on Programming

- Transportation engineers are deep in “big data” or “data science”: more and more data is coming our way and spreadsheets are ill-suited for the task
  - Computing is the new math
- Prototyping ! = software engineering
  - iterative development: interpreter and interactive data exploration and processing (e.g. Python with scientific packages)
  - “premature optimization is the root of all evil”

Performance

Feature tracking performance depends on video resolution and special post-processing requirements such as stabilisation or lens correction (for distortion). A typical one hour 800×600 *video is processed with current consumer-grade hardware in about an hour. A typical one hour* 1280×960 *video with correction for distortion can be processed in about two hours.*
Basic analysis on one of these trajectory sequences takes between 5 minutes and 30 minutes, depending on traffic in the scene, while conflict analysis, particularly motion patterns, can typically take anywhere between 1 to 48 hours to complete. Conflict analysis processing times are very sensitive to the interaction complexity of the scene.

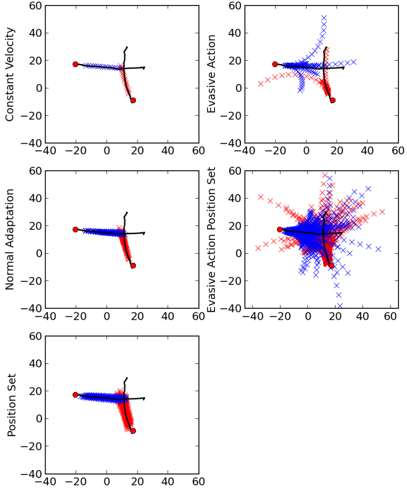
(Intel Core i7 3770k CPU) [St-Aubin et al., 2014]

Other Characteristics

- Multi-platform: C++ compiles on Windows and Linux, Python
- Documentation (Doxygen) and explicit naming
- The program is (partially) tested
- Python modules: cvutils, events, indicators, metadata, ml, moving, (objectsmoothing, pavement, poly-utils,) prediction, (processing,) storage, (traffic_engineering,) ubc_utils, utils
- Python scripts: (classify-objects.py,) display-trajectories.py, safety-analysis.py, compute-clearmot.py, play-video.py, compute-homography.py, (train-object-classification.py,), create-bounding-boxes.py, undistort-video.py, delete-tables.py(, rescale-homography.py)

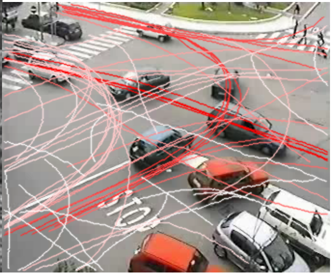
Outline

Step 4: Motion Prediction



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”

Step 4: Motion Prediction



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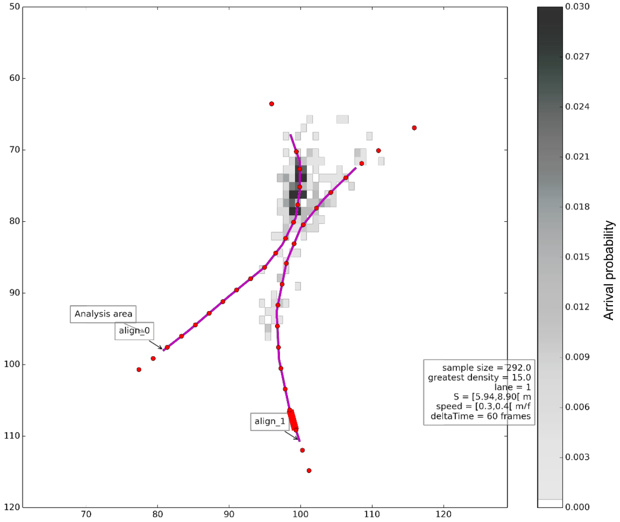
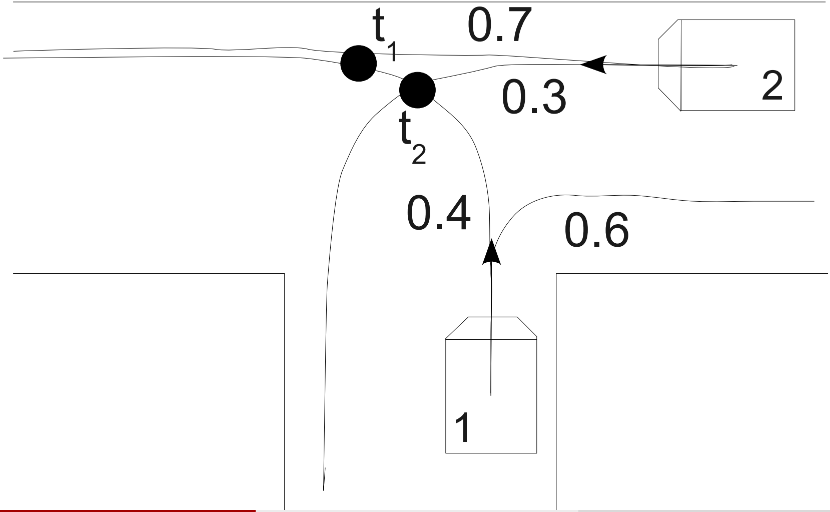


Step 5: Safety Indicators



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Using of a finite set of predicted trajectories, enumerate the collision points CP_n and the crossing zones CZ_m. Safety indicators can then be computed:

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

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

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

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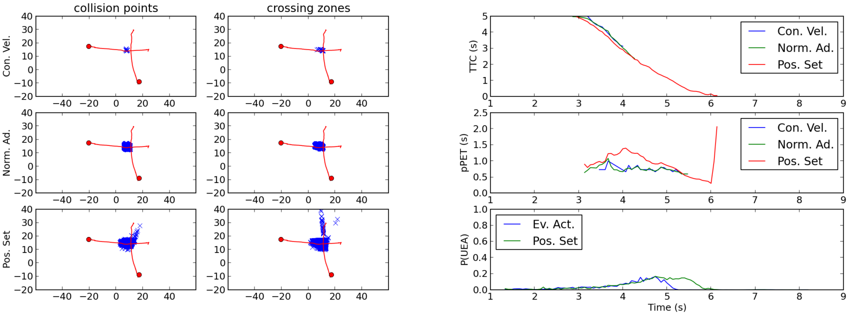

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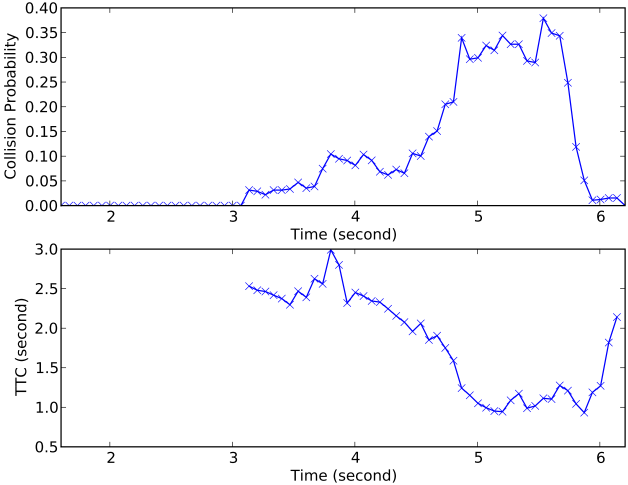

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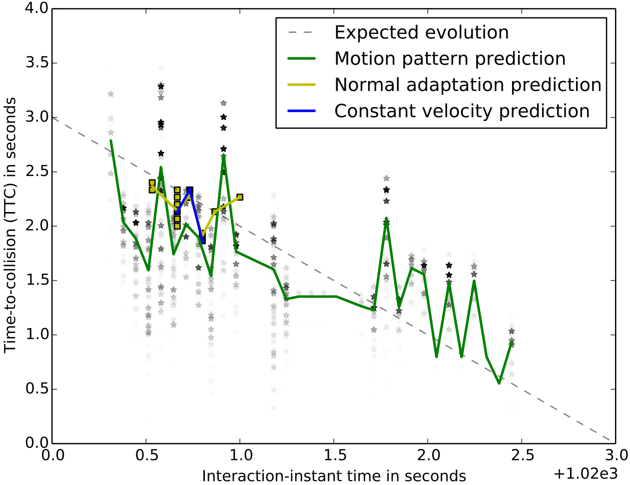
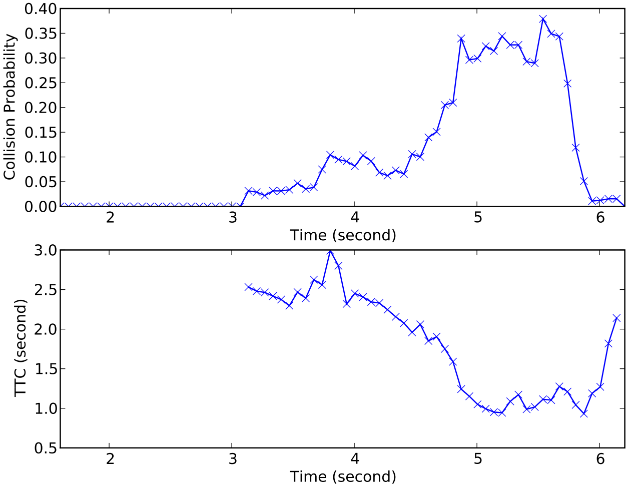


Step 6: Interpretation

For each interaction, we have



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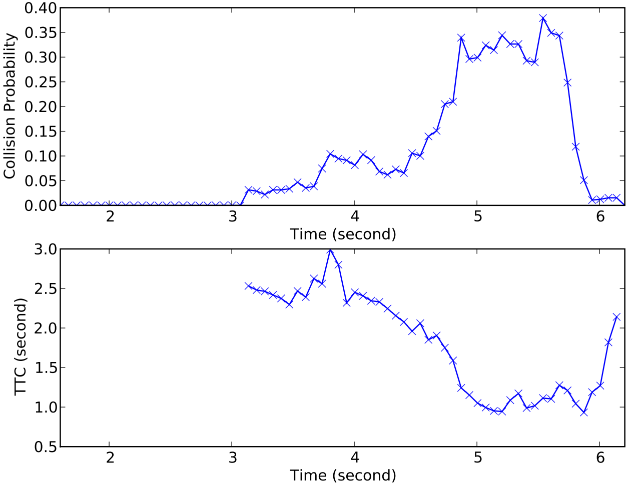
How should data be aggregated?



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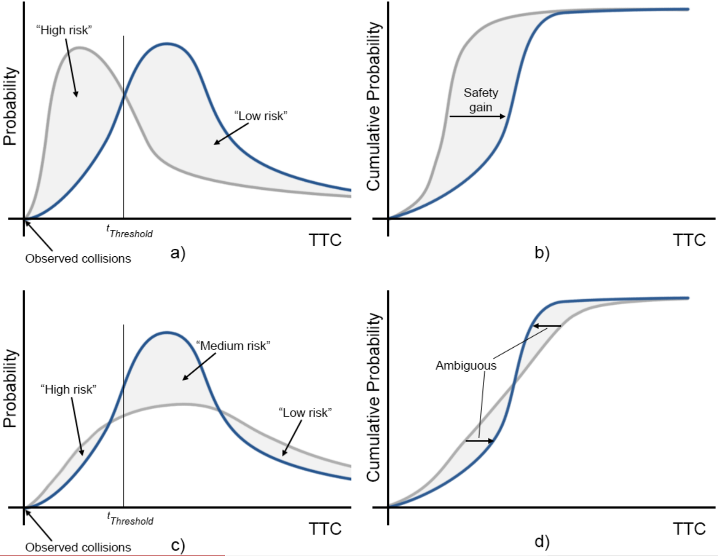

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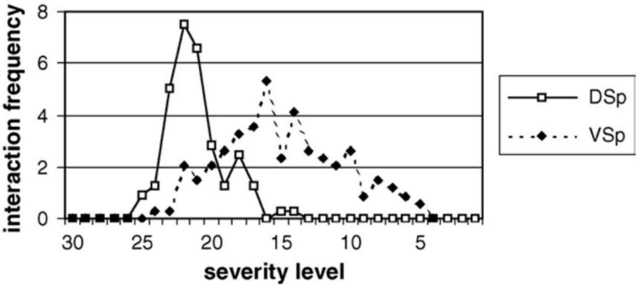
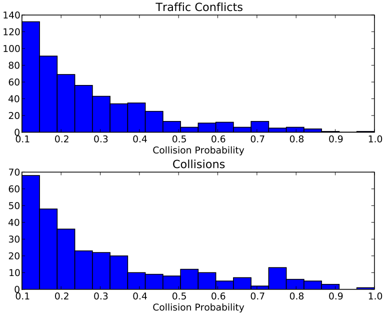


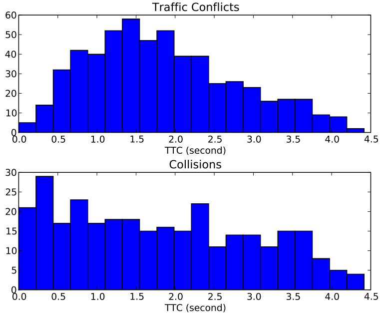
Fig. 6. Interaction frequency (interactions per observation hour) for different severity levels. Straight ahead driving vehicles versus pedestrians. The pedestrian is taking evasive action. A non-signalised intersection (DSp) and a signalised intersection (VSp).

Step 6: Interpretation

Maximum Collision Probability



Minimum TTC



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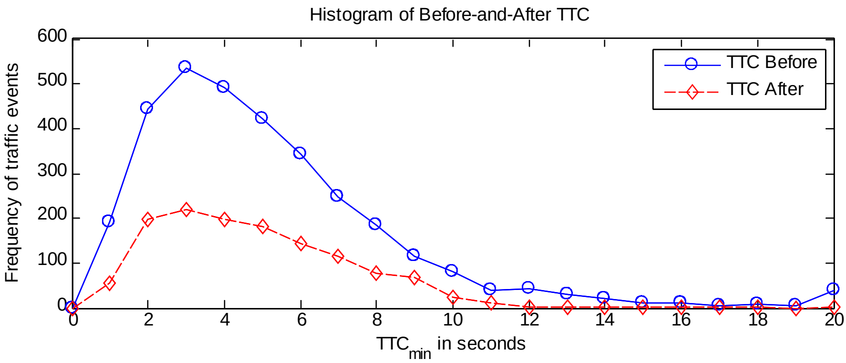

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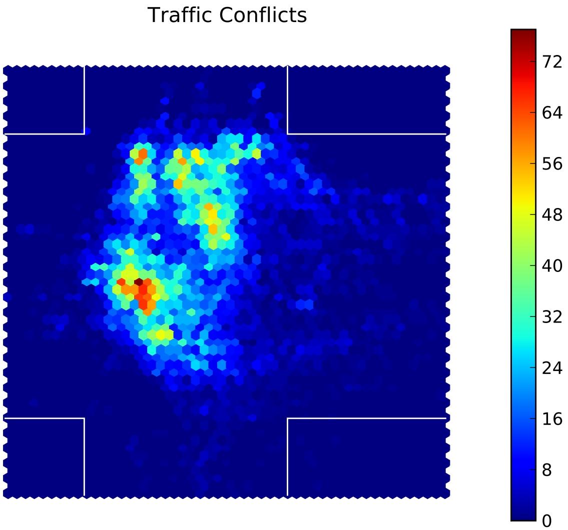

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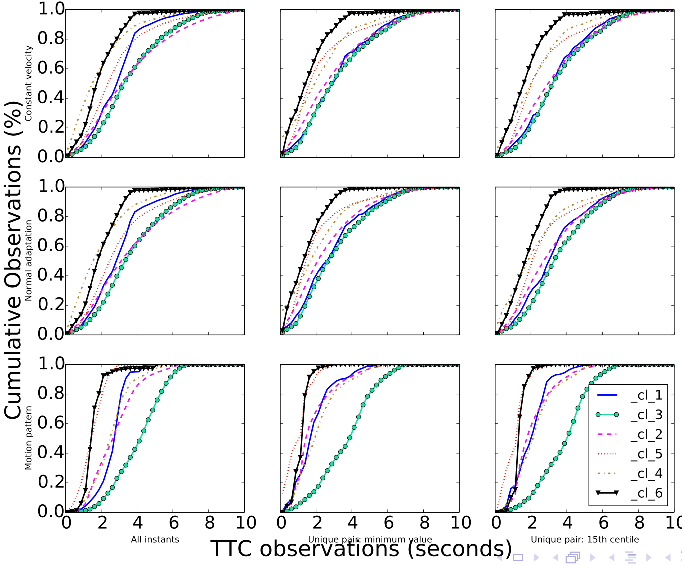

Step 6: Interpretation

	Model I. Cycle track on the right vs. no cycle track			Model II. Cycle track on the left vs. no cycle track			Model III. Cycle track on the right vs. cycle track on the left		
	Coef.	Std. Err.	Sig.	Coef.	Std. Err.	Sig.	Coef.	Std. Err.	Sig.
Cycle Track on Right	0.395	0.181	0.03	-	-	-	-	-	-
Cycle Track on Left	-	-	-	Not Significant			-0.513	0.131	0.00
Bicycle Flow for 5s before to 5s after	Not Significant			0.088	0.038	0.02	0.066	0.034	0.05
Turning-Vehicle Flow for 5s before to 5s after	-2.771	0.132	0.00	-3.265	0.090	0.00	-3.131	0.080	0.00
Number of Lanes on the Main Road	-0.151	0.078	0.05	Not Significant			Not Significant		
Number of Lanes on the Turning Road	Not Significant			0.324	0.146	0.03	0.457	0.178	0.01
Cut-off 1	-6.599	0.353	0.00	-7.372	0.301	0.00	-7.621	0.323	0.00
Cut-off 2	-4.233	0.273	0.00	-3.807	0.223	0.00	-4.125	0.265	0.00
Cut-off 3	-3.150	0.256	0.00	-2.102	0.211	0.00	-2.479	0.258	0.00
Number of Observations	2880			4803			6567		
Log likelihood	-804			-1876			-2330		

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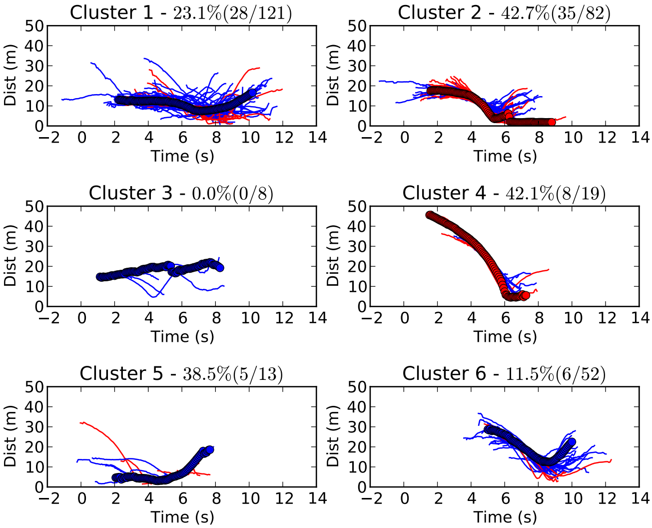

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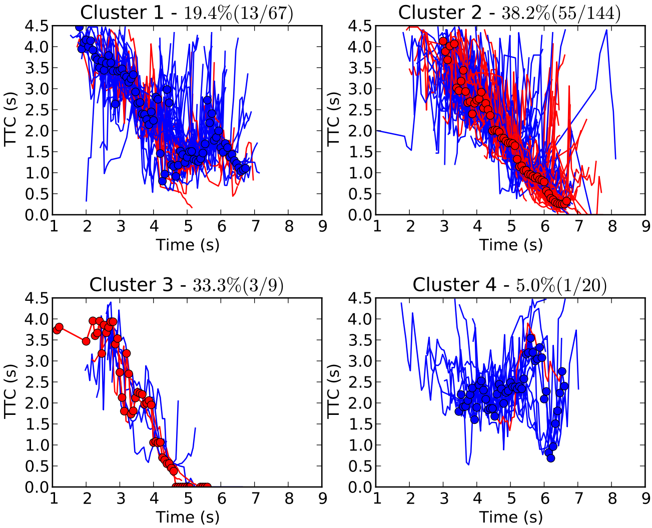

Outline

Lane-Change Bans at Urban Highway Ramps

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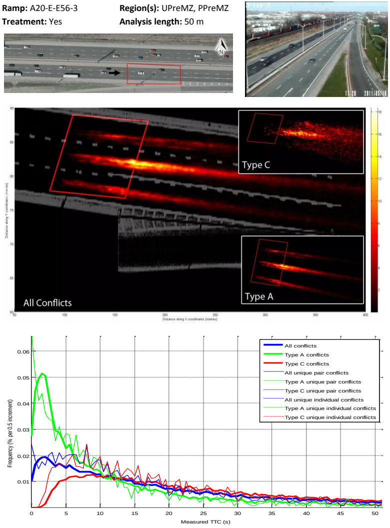


Figure 37 – Conflict analysis Cam20-16-Dorval (Treated).

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

Lane-Change Bans at Urban Highway Ramps

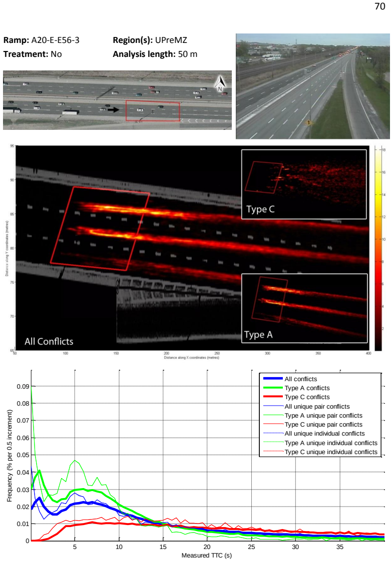
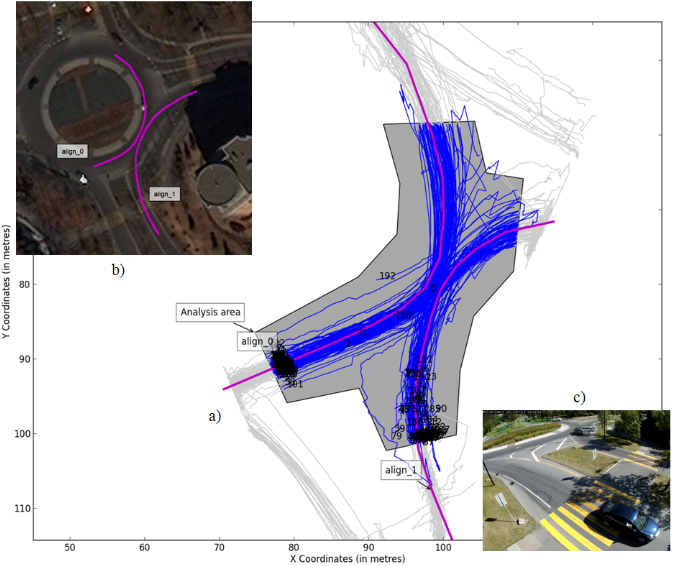


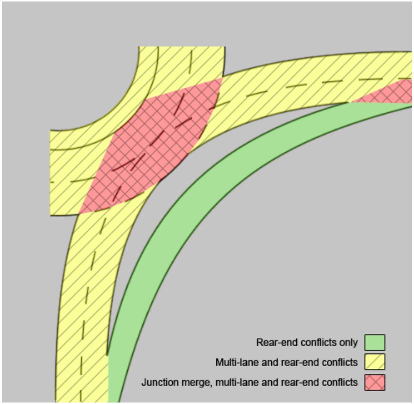
Figure 27 – Conflict analysis Cam20-16-Dorval (Untreated).

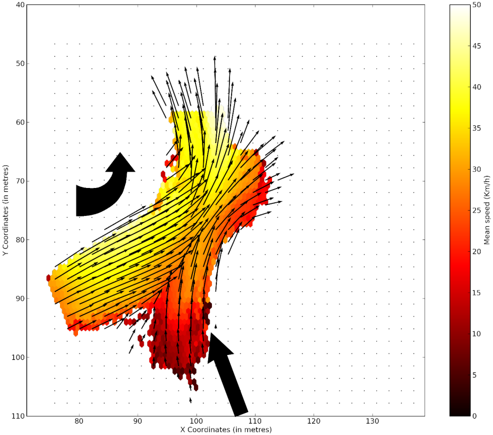
Untreated site (no lane marking) [St-Aubin et al., 2012, St-Aubin et al., 2013a]

Big Data: Roundabout Safety in Québec



Speed Fields in Roundabouts



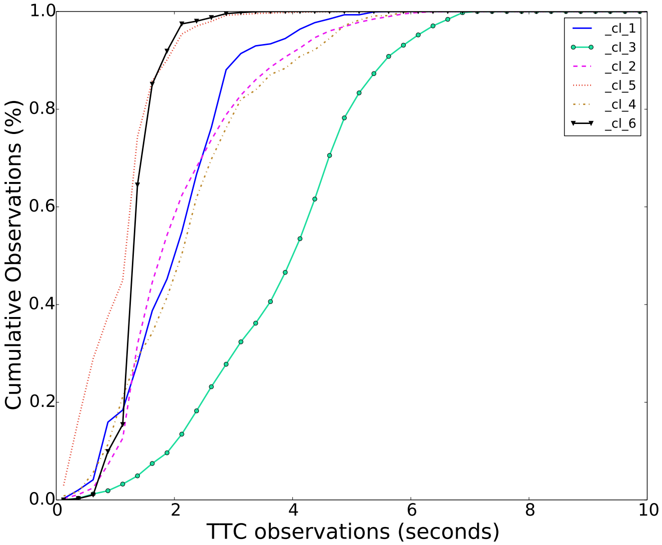


[St-Aubin et al., 2013b]

K-means cluster profile for TTC regression

#	Description	N_{zones}	N_{obs}
1	Small single and double lane residential collectors	11	4,200
2	Single-lane regional highways and arterials with speed limits of 70-90 km/h and mostly polarized flow ratios	16	26,243
3	2-lane arterials with very high flow ratios	5	13,307
4	Hybrid lane 1$-$ $>$2 2$-$ $>$1 arterials with very low flow ratios	3	4,809
5	Traffic circle converted to roundabout (2 lanes, extremely large diameters, tangential approach angle)	4	10,295
6	Single-lane regional highway with large-angle quadrants (140 degrees) and mixed flow ratios	2	2,235

TTC Distribution Comparison by Cluster



Analysis of Bicycle Facilities in Montreal

- Bicycle boxes (only 4 in Montreal)

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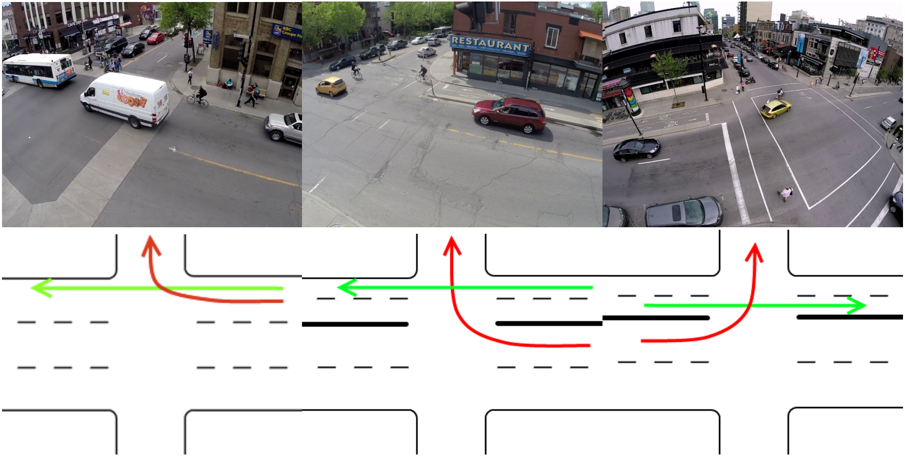
- Cycle tracks: 650 km of bicycle network in 2015

Model of Dangerous Interactions at Bicycle Boxes

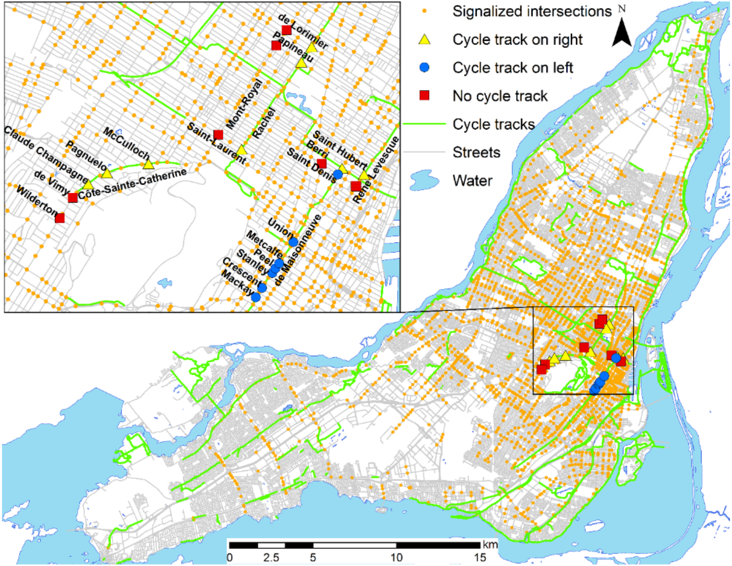
Explanatory variables	Interaction Type 1						Interaction Type 2					
	Interaction (PET < 5s)			Dangerous Interaction (PET < 1.5s)			Interaction (PET < 5s)			Dangerous Interaction (PET < 1.5s)		
	Coef.	p-val.	Elas.	Coef.	p-val.	Elas.	Coef.	p-val.	Elas.	Coef.	p-val.	Elas.
Constant	-0.559	0.00	-	-1.954	0.00	-	-2.994	0.00	-	-4.354	0.00	-
Bicycle Flow during 30s before	0.423	0.00	7.7 %	0.434	0.00	2.1 %	-	-	-	-	-	-
Vehicle Flow 1 during 30s before	0.091	0.00	1.6 %	0.040	0.04	0.2 %	0.063	0.00	0.4 %	-	-	-
Vehicle Flow 2 during 30s before	-0.086	0.00	-1.6 %	-0.082	0.01	-0.4 %	0.117	0.00	0.8 %	0.097	0.00	0.1 %
Presence of Bicycle Box	**-0.739**	**0.00**	**-14 %***	**-1.226**	**0.00**	**-7 %***	**-0.726**	**0.00**	**-5 %***	**-2.050**	**0.00**	**-2 %***
Observations	1054						1054					
Percentage of positive obs.	27.6 %			7.5 %			9.8 %			1.3 %		
Log-likelihood	-544.00			-251.48			-299.85			-66.44		
Pseudo R^2	0.133			0.109			0.117			0.110		

* Elasticity for discrete change of dummy variable from 0 to 1

Turning Vehicle Interactions with Cycle Tracks



Site Selection

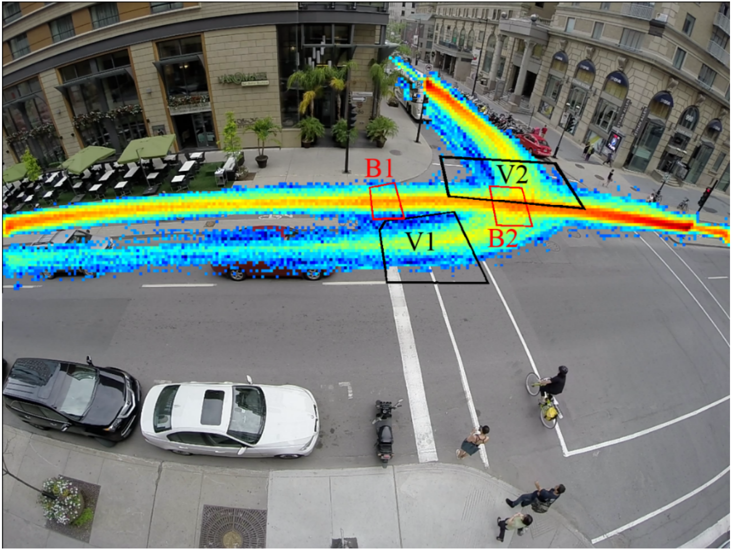


Site Selection

	# intersections	Duration
Cycle track on the right	8 intersections	37 h
Cycle track on the left	7 intersections	22 h
No cycle track	8 intersections	31 h
Total	23 intersections	90 h

Videos were collected on weekdays during the evening peak period from 3pm to 7pm

Road User Selection



Three PET Ordered Logit Models

	Model I. Cycle track on the right vs. no cycle track			Model II. Cycle track on the left vs. no cycle track			Model III. Cycle track on the right vs. cycle track on the left		
	Coef.	Std. Err.	Sig.	Coef.	Std. Err.	Sig.	Coef.	Std. Err.	Sig.
Cycle Track on Right	0.395	0.181	0.03	-	-	-	-	-	-
Cycle Track on Left	-	-	-	Not Significant			-0.513	0.131	0.00
Bicycle Flow for 5s before to 5s after	Not Significant			0.088	0.038	0.02	0.066	0.034	0.05
Turning-Vehicle Flow for 5s before to 5s after	-2.771	0.132	0.00	-3.265	0.090	0.00	-3.131	0.080	0.00
Number of Lanes on the Main Road	-0.151	0.078	0.05	Not Significant			Not Significant		
Number of Lanes on the Turning Road	Not Significant			0.324	0.146	0.03	0.457	0.178	0.01
Cut-off 1	-6.599	0.353	0.00	-7.372	0.301	0.00	-7.621	0.323	0.00
Cut-off 2	-4.233	0.273	0.00	-3.807	0.223	0.00	-4.125	0.265	0.00
Cut-off 3	-3.150	0.256	0.00	-2.102	0.211	0.00	-2.479	0.258	0.00
Number of Observations	2880			4803			6567		
Log likelihood	-804			-1876			-2330		

Outline

Framework for the Calibration and Validation of Traffic Micro-simulation

- Terrible state of practice (MULTITUDE project)

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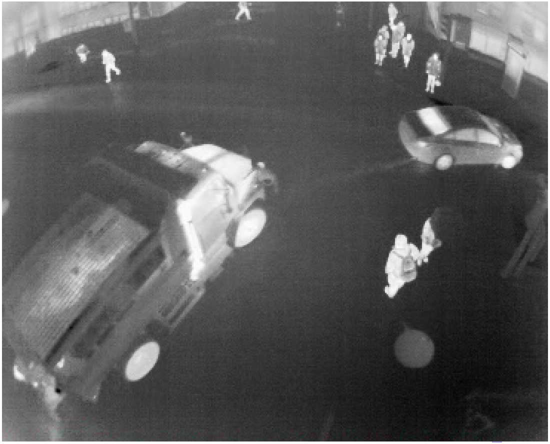
- Partnership with WSP (consulting company)

Night-time Safety

- Study of the link between lighting and safety [Nabavi Niaki et al., 2014]
- Night-time observations: video data from thermal camera



Open Questions for Surrogate Measures of Safety

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- How can we compare the various methods and indicators?
- How do we validate the methods? With respect to what?
- How do we account for exposure? Conflicts are, by definition, not exposure [Hauer, 1982]

Other Interests

- Traffic monitoring, probe data
- Naturalistic driving studies
- Advanced Driver Assistance Systems and vehicle automation
  - project for the Ministry of Transportation on experimentations on the safety impact of Intelligent Speed Adaptation and Speed Data Loggers
  - Senior associate of the Canadian Automated Vehicles Centre of Excellence (CAVCOE)

- Collaboration with Tarek Sayed (UBC), Karim Ismail (Carleton), Mohamed Gomaa Mohamed, Paul St-Aubin, Matin Nabavi Niaki (Polytechnique Montréal), Luis Miranda-Moreno, Sohail Zangenehpour (McGill), Aliaksei Laureshyn (Lund)
- 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), City of Montreal

Questions?

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