Automated Vehicle Safety Monitoring and Human-Vehicle Communication

INTonomous Virtual Fair

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Outline

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Why Automating Road Vehicles?

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- 1.35 million people die each year on the world's roads
- millions more are severely injured
- 54 % of those dying on the world's roads are vulnerable road users

(Road Traffic Injuries, World Health Organization)

Why Automating Road Vehicles?

$\approx$ 95 % of accidents involve human factors

How To Prove Automated Vehicles (AVs) are Safer than Humans?

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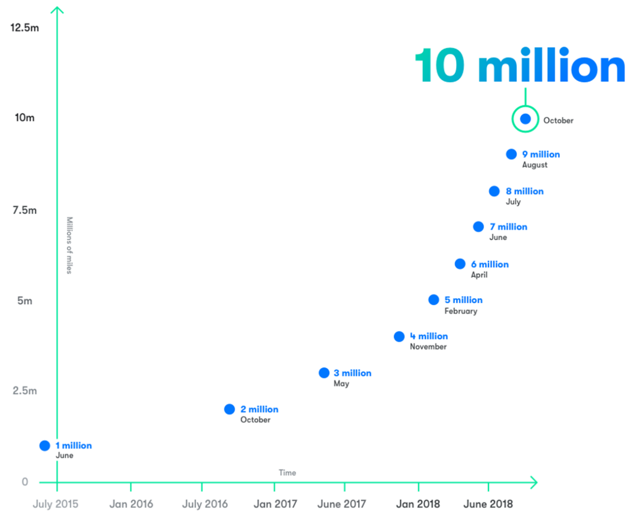
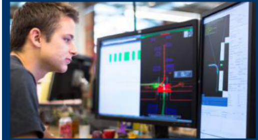
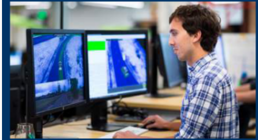


10 million miles and counting

How To Prove Automated Vehicles (AVs) are Safer than Humans?





Waymo engineers build virtual scenarios that allow our self-driving vehicles to drive up to 8 million simulated miles each day.

Simulation: How the Virtual World Helps Our Cars Learn Advanced Real-World Driving Skills

Waymo's simulator can replay the real-world miles we have driven with each new software version, but also can build completely new realistic virtual scenarios for our software to be tested against. Each day, as many as 25,000 virtual Waymo self-driving vehicles drive up to eight million miles in simulation, refining old skills and testing out new maneuvers that help them navigate the real world safely.

For example: at the corner of South Longmore Street and West Southern Avenue in Mesa, Arizona, there's a flashing yellow arrow for left turns. This type of intersection can be tricky for humans and self-driving vehicles alike — drivers must move into a five-lane intersection and then find a gap in oncoming traffic. A left turn made too early may pose a hazard for oncoming traffic; a turn made too late may frustrate drivers behind.

Simulation lets us turn a single real-world encounter like this into thousands of opportunities to practice and master a skill.

5 billion self-driven miles simulated → regression testing

How To Prove Automated Vehicles (AVs) are Safer than Humans?

"With millions of miles driven through countless situations on public roads, and billions more in simulation, we've gathered incredible amounts of data and invaluable lessons to develop autonomous driving technology further than anyone else"

"The Waymo Driver takes the information it gathers in real time, as well as the experience it has built up over its 20+ million miles of real world driving and 20+ billion miles in simulation, to anticipate what other road users might do"

(`https://waymo.com/waymo-driver/`, January 2022)

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This is also an advantage as software can be instantaneously updated in the whole fleet to fix issues

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Can we simply have AVs pass a driving license?
This is insufficient. A person being licensed has extensive experience and knowledge, e.g. about the physics of the world.

Assuming AVs are Safe

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Yes, monitoring will be needed: defects will occur, vehicles are constantly updated and might be tampered with, by their owners or hackers

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Because there will be pedestrians and we want to encourage active modes of transportation (walking, cycling)

Information and Communications in Current Road Traffic

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- Vehicles: movement, vehicle lights (turning, braking)
- Users: movement, gestures, gaze

Principles of Traffic Control Devices

"To be effective, a traffic control device should meet five basic requirements:

1. *Fulfill a need;*
2. *Command attention;*
3. *Convey a clear, simple meaning;*
4. *Command respect from road users; and*
5. *Give adequate time for proper response."*

"Uniformity of the meaning of traffic control devices is vital to their effectiveness"

"Uniformity of devices simplifies the task of the road user because it aids in recognition and understanding, thereby reducing perception/reaction time." (MUTCD)

Connected Vehicles

- Vehicle to infrastructure (V2I) communication
- Vehicle to vehicle (V2V) communication
- Vehicle to pedestrian (V2P), cyclist, etc. communication

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When is this going to happen and more importantly, is that a viable future?

Information and Communications for the Foreseeable Future with AVs

- AVs must understand human intent
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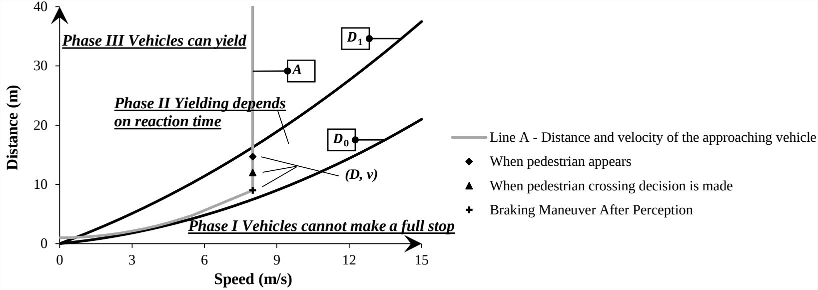
We need to study the interactions of AVs with pedestrians and cyclists

- using direct traffic observations, e.g. video data, computer vision, behaviour and safety indicators

Outline

Methods: Distance-Velocity Framework



Work with Ting Fu and Luis Miranda-Moreno, McGill University

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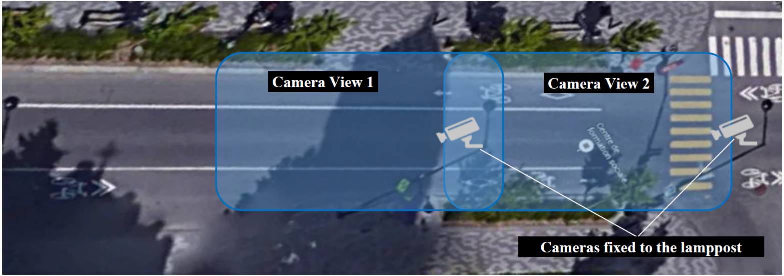
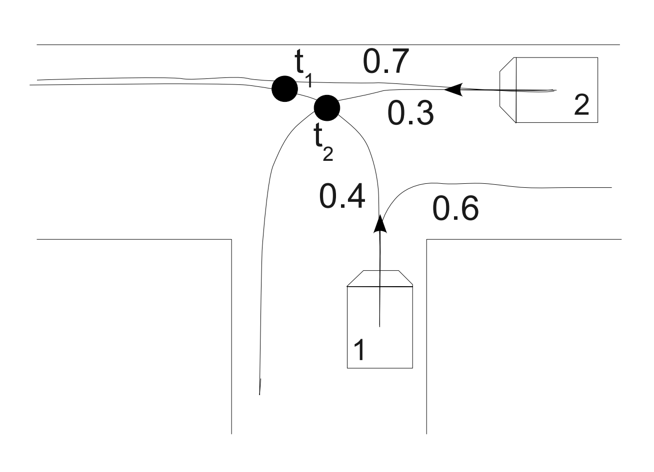


a) Camera locations and installations on the aerial map

b) Trajectories of the same vehicle through multiple cameras (displayed on the video frames after the correction for lens

Methods: Surrogate Measures of Safety



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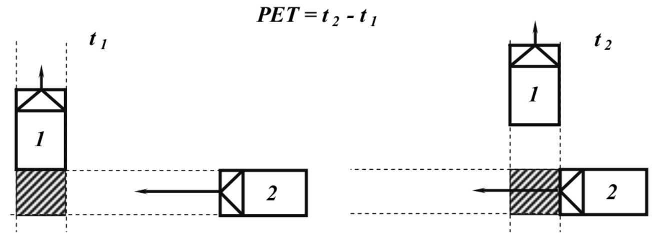
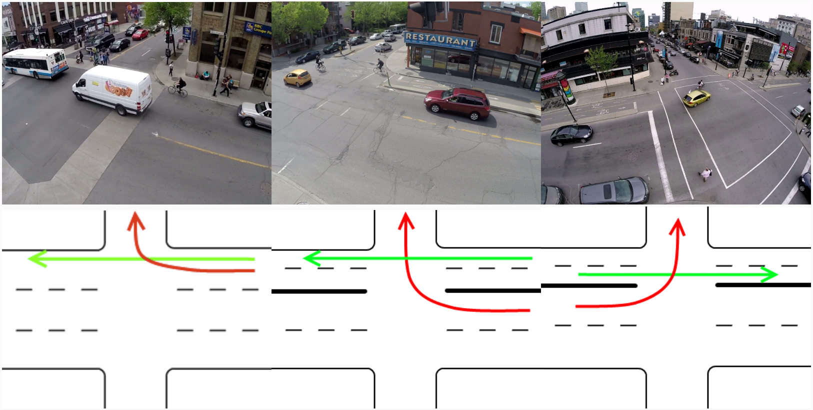


Turning Vehicle Interactions with Cycle Tracks



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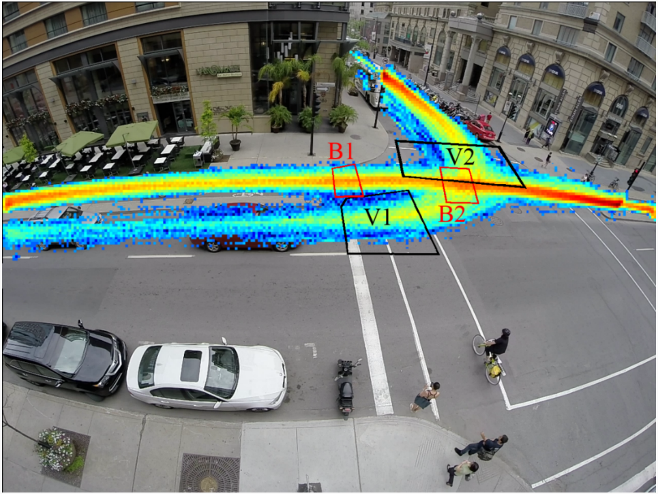

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Turning Vehicle Interactions with Cycle Tracks

	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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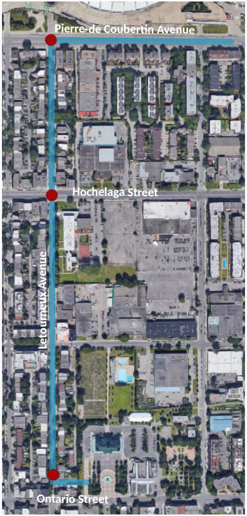
Study of Low-Speed Automated Shuttle in Montreal and Candiac



Work with Étienne Beauchamp and Marie-Soleil Cloutier, INRS

Study of Low-Speed Automated Shuttle

Montreal

Pierre-de-Coubertin	Hochelaga
	

Ontario

Study of Low-Speed Automated Shuttle

Candiac

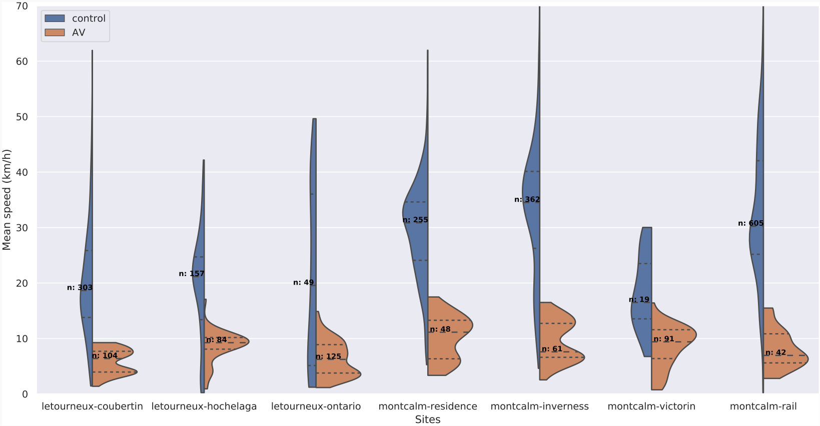
Residence

Inverness

Marie-Victorin

Rail

Study of Low-Speed Automated Shuttle



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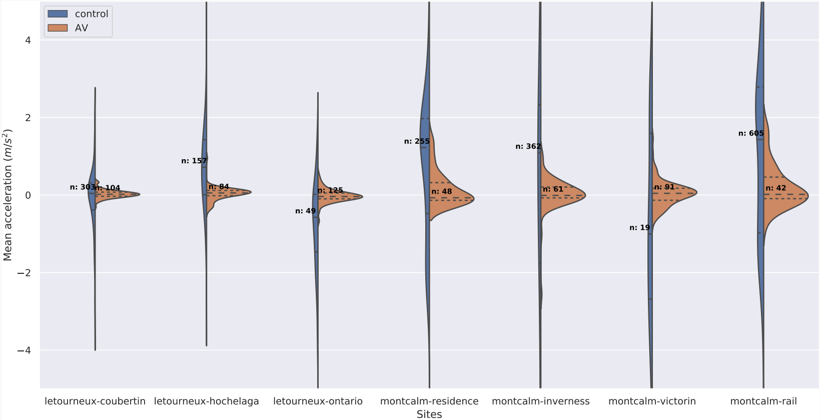

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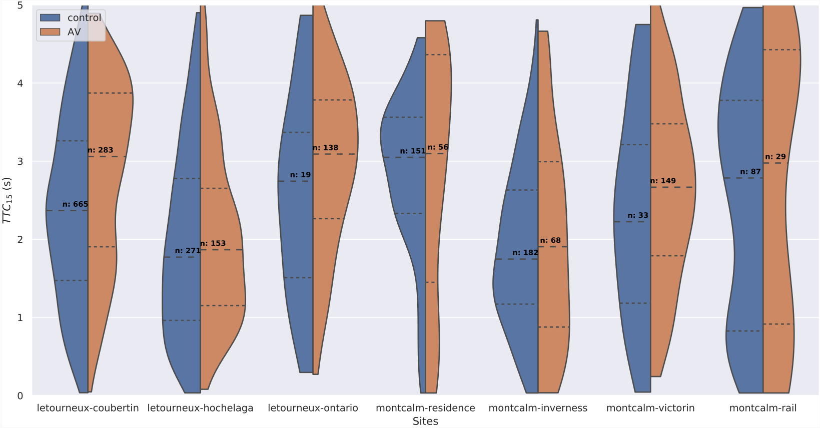

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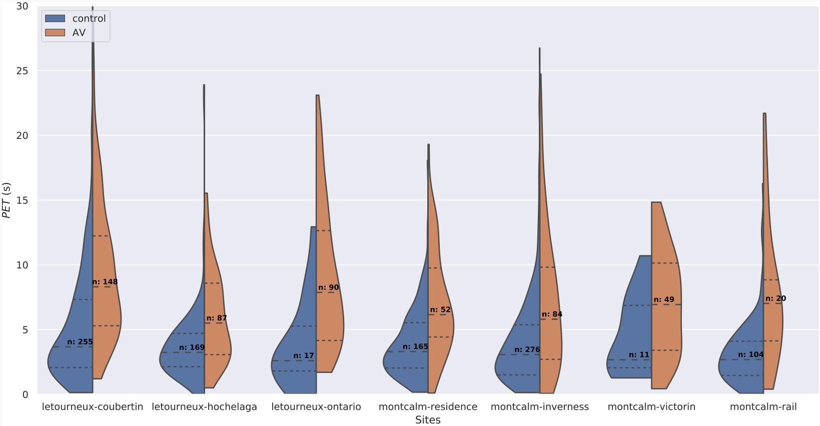

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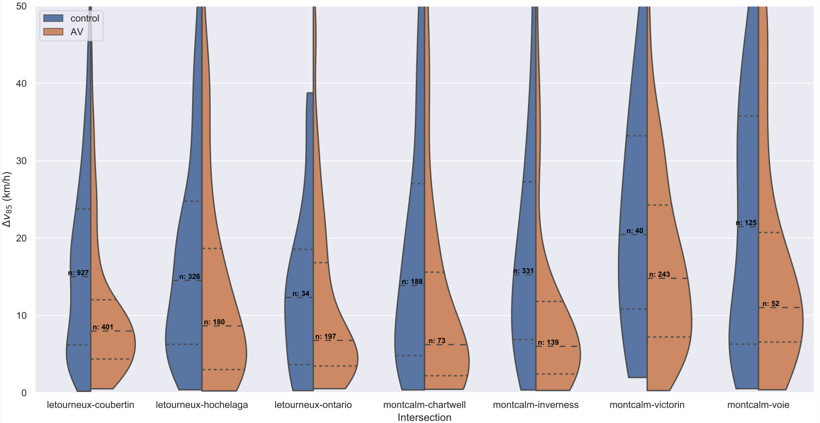

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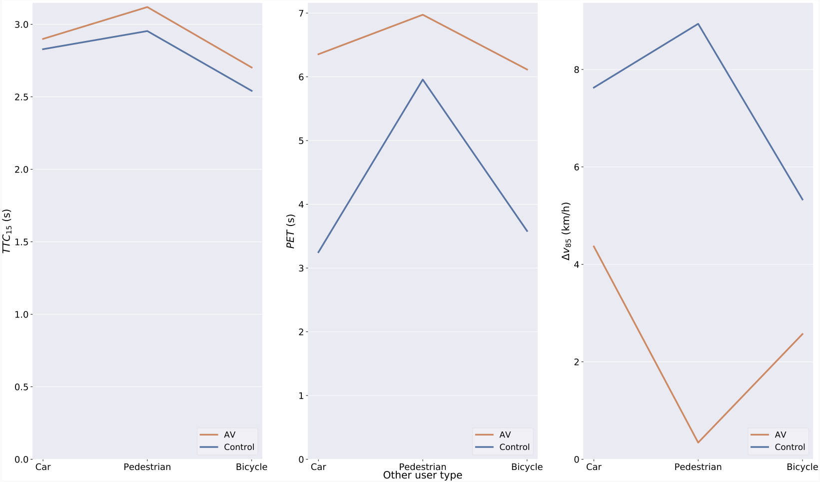

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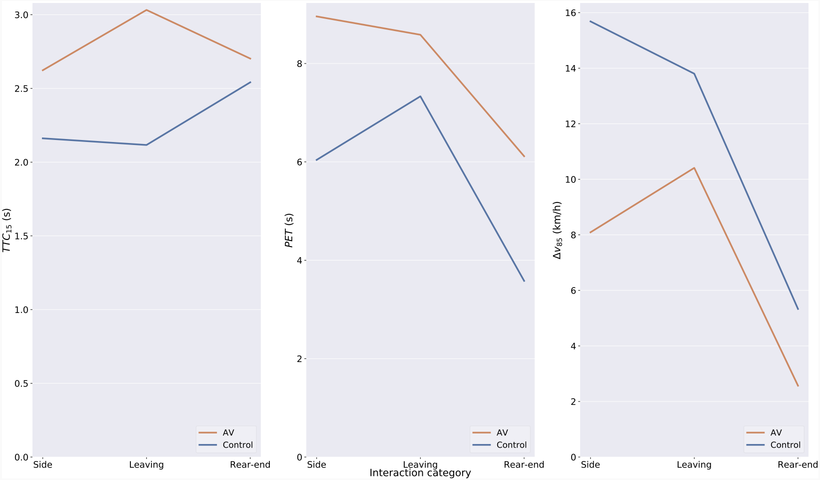

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- Human factors are tricky and cannot be “technologized away”
- Human-vehicle communications must be standardized
- AV interactions in traffic must be monitored independently

Questions?