Applying ML Techniques to Connected Autonomous Vehicles

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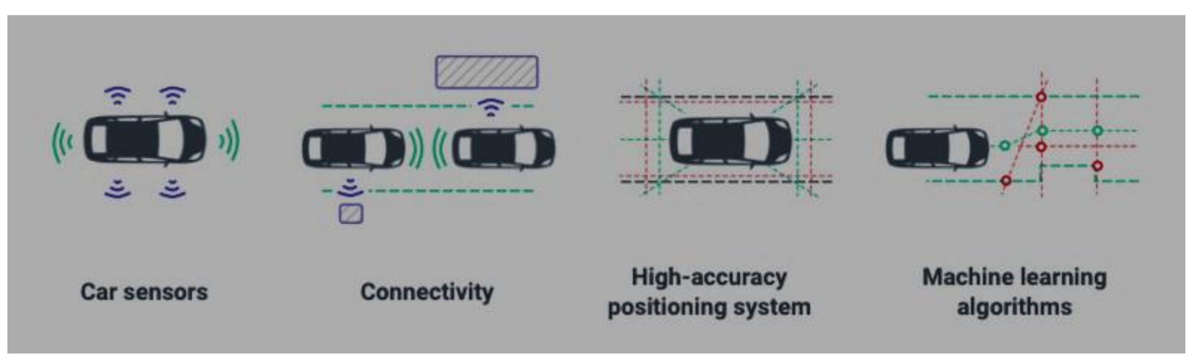
Research context and motivation

- With more than 1.35 million worldwide road casualties annually, people's safety is an utmost concern in the automotive sector
- Intersection crossings are one of the most dangerous sections of the road infrastructure and are responsible for a significant number of accidents

- New generation connected vehicles alleviate that concern by exchanging critical information between infrastructures and/or vehicles
- In addition, new-gen vehicles can collect/generate a massive amount of data through their extensive array of sensing devices and ECU's
- Machine Learning (ML) algorithms can utilize the data generated by the vehicles to develop data-driven decision-making models and enhance the driving assistance systems to react to the ever-changing environment
- With the inception of autonomous vehicles is near, machine learning algorithms play a crucial role in perceiving and understanding the world around a car

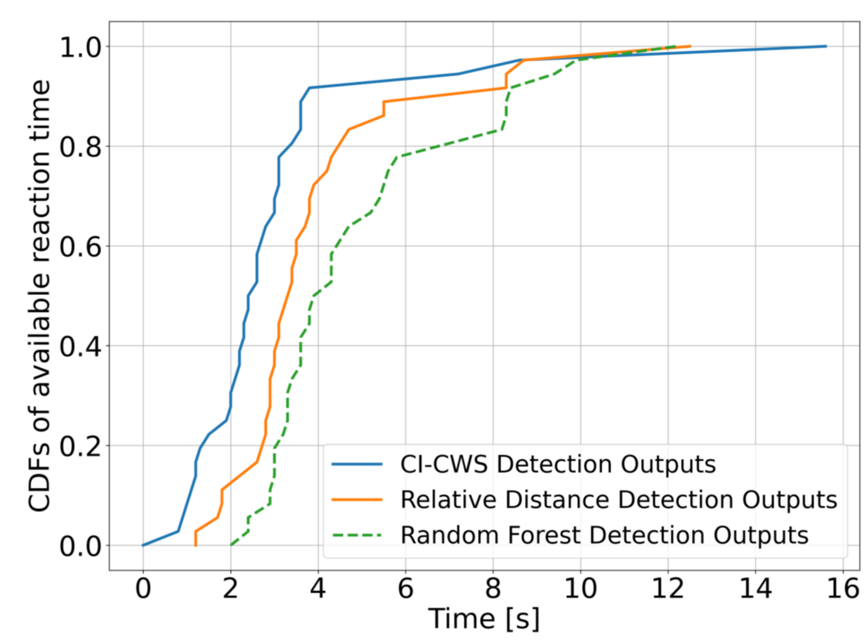


Novel contributions

- Collision detection/avoidance mechanism based on ML-aided uncertainty-aware trajectory prediction at urban intersections
- Evaluated using the synthetic mobility traces from Luxembourg SUMO traffic scenario
- LSTM ED model uses past 3 seconds of vehicle's information to predict next 3 seconds of trajectory
- CDF of the prediction errors reveals:
  - 89.81% T+1 error of < 1 m
  - 94.25% T+3 errors < 3 m

Prediction Time [s]	Quantile Estimation [%]			
	0.9		0.1	
	Long. Position	Lat. Position	Long. Position	Lat. Position
T+1	93.09	92.65	5.11	2.55
T+2	94.73	90.76	2.54	3.41
T+3	93.73	90.17	3.48	4.58

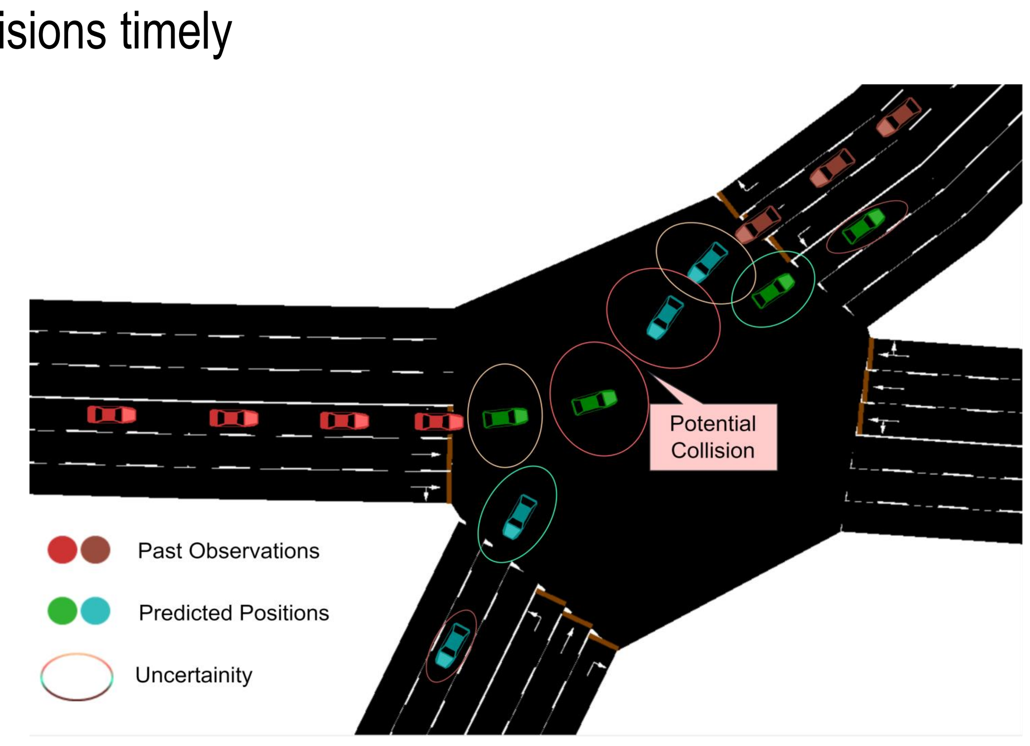
- Quantiles 0.9 and 0.1 presents the ratio of true vehicle positions below the predicted output



- Uncertainty estimation allows the Random Forest model to identify collisions earlier
- <0.05% False Positive (FP) rate
- Central entity at the intersection notify vehicles in the collision course to initiate the corrective action
- Able to avert predicted collisions with the deceleration rate of $9ms^{-2}$ while the intensity of the collisions were reduced with $4.5ms^{-2}$ deceleration rate

Addressed research questions/problems

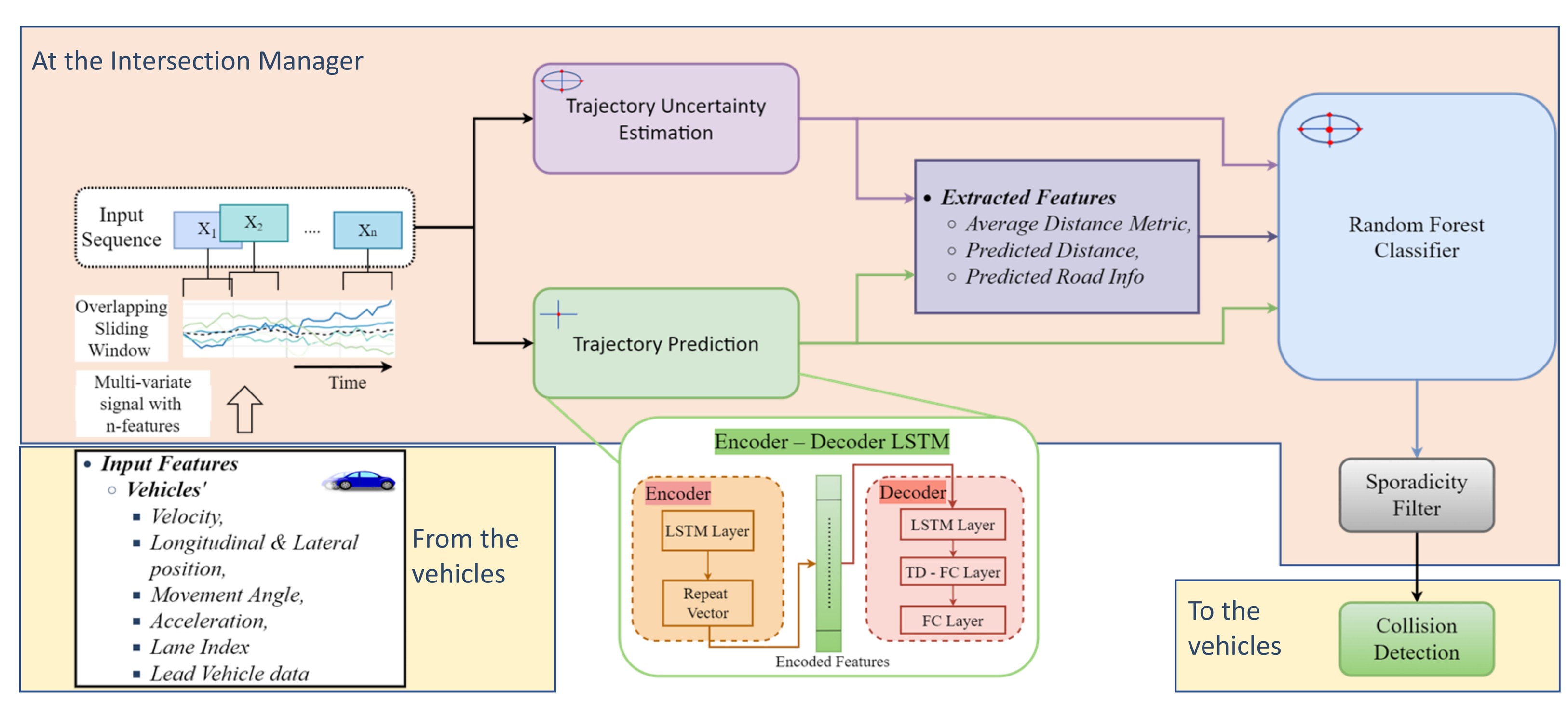
- Few approaches have already been proposed to predict the trajectories of Connected Vehicles (CVs) and use them to detect collisions. However, these approaches lack the precision required for reliable collision detection in a complex driving environment, i.e., intersections
- In general, the predicted trajectories present the vehicle's future positions solely as point estimates, which are insufficient for detecting collisions at dense urban crossroads.
- In addition, we need to estimate the uncertainties associated with the predicted trajectories to detect the collisions timely



- Collision detection algorithms need timely updated data to foresee the collisions effectively.
  - → Multi-access Edge Computing (MEC) platform with both V2I and I2I communications are used to collect relevant data at an edge entity
- Machine Learning based approaches to:
  - → accurately predict the vehicle trajectories
  - → estimation of the associated prediction reliability
- Reliable collision detection mechanism that uses both trajectory predictions and prediction intervals to foresee possible collision events and reduce false positives

Adopted methodologies

- Two Long Short Term Memory (LSTM) based Encoder-Decoder (ED) model setup predicts the vehicle's trajectory and estimates its associated uncertainty
- Trajectory prediction ED model reduces the Mean Squared Error of the predicted trajectory
- Uncertainty Estimation ED model minimizes the quantile loss function to provide lower and upper estimates of the predicted trajectory
- Random Forest Classifier combines vehicle's trajectory and uncertainty estimates to predict the collision between two vehicles



Future work

- Exploring domain adaptation/transfer learning techniques to generalize the proposed framework
- Exploring Human-in-the-Loop based DRL setup to allow customizable driving behavior and reduce the human interventions in automated vehicles

Submitted and published works

- D. C. Selvaraj, S. Hegde, C. F. Chiasserini, N. Amati, F. Deflorio, and G. Zennaro, "A Full-fledge Simulation Framework for the Assessment of Connected Cars", Transportation Research Procedia, Vol. 52, 2021, pp. 315-322
- D. C. Selvaraj, C. Vitale, T. Panayiotou, P. Kolios, C. F. Chiasserini and G. Ellinas, "Edge Learning of Vehicular Trajectories at Regulated Intersections", IEEE 94th Vehicular Technology Conference (VTC2021-Fall), Online, 2021, pp. 1-7
- D. C. Selvaraj, S. Hegde, N. Amati, C. F. Chiasserini, and F. Deflorio, "A reinforcement learning approach for efficient, safe and comfortable driving", 24th EURO Working Group on Transportation Meeting (EWGT), Aveiro, 2021.
- D. C. Selvaraj, C. Vitale, T. Panayiotou, P. Kolios, C. F. Chiasserini and G. Ellinas, "ML-aided Uncertainty-aware Vehicle Collision Detection at Urban Intersections," in preparation for submission to a journal.
- D. C. Selvaraj, S. Hegde, N. Amati, F. Deflorio, and C. F. Chiasserini, "An ML-aided Reinforcement Learning Approach for Challenging Vehicle Maneuvers," submitted to IEEE Transactions on Intelligent Vehicles

List of attended classes

- 01TRARV – Big data processing and programming (13/8/2021, credits: 4)
- 01DTPRV – Connected Vehicles (didattica di eccellenza) (23/6/2022, credits: 4)
- 01QTEIU – Data mining concepts and algorithms(1/2/2021, credits: 4)
- 01UNRRV – Entrepreneurship and start-up creation (31/5/2021, credits: 8)
- 02SFURV – Programmazione scientifica avanzata in matlab (26/5/2022, credits: 6)
- 02QUBRS – Statistical data processing (4/2/2021, credits: 4)
- 01QFFRV – Tecniche innovative per l'ottimizzazione (23/7/2021, credits: 4)
- 01QORRV – Writing Scientific Papers in English (16/6/2022, credits: 3)
- 01DPIRO – Advanced Topics in Energy Storage System and Electric Vehicle Drivetrain Design (didattica di eccellenza) (7/9/2022, credits: 4)