PhD student Nicola Albarella

Control architectures for Advanced Driver Assistance Systems in automotive

Tutor: prof. Stefania Santini

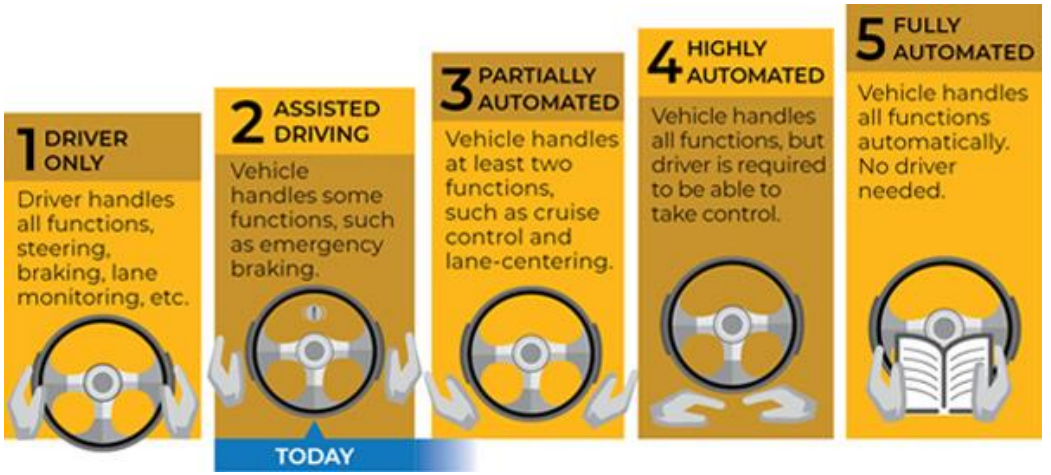
Cycle: XXXV Year: SECOND

My background

- MSc degree: Automation Engineering
- Research group/laboratory: Daisy Lab (Prof. Stefania Santini)
- PhD start date: 01/11/2019
- Scholarship type: company-funded scholarship
- Partner company: Kineton s.r.l.

Research topic

- Design and validation of control algorithms for Advanced Driving Assistance Systems (ADAS)
- The aim is to define planning and control laws in order to enhance safety of the self-driving cars
  - Moreover, purposely integrated co-simulation platforms are needed to verify the control architectures

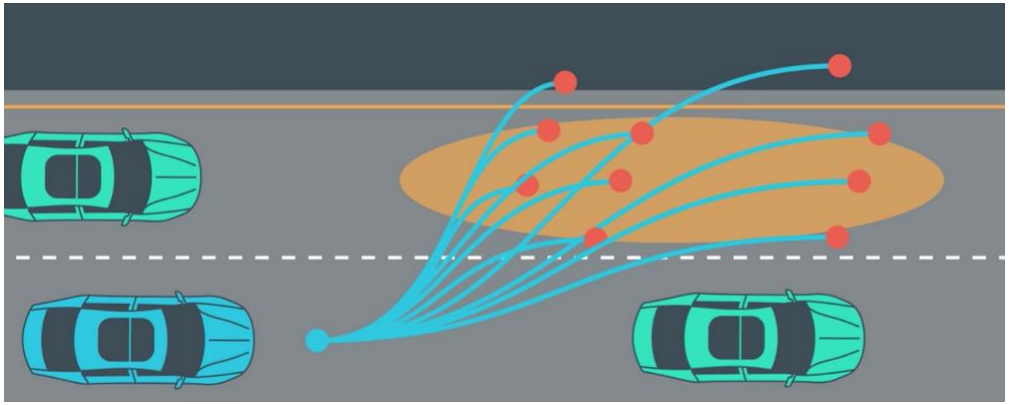


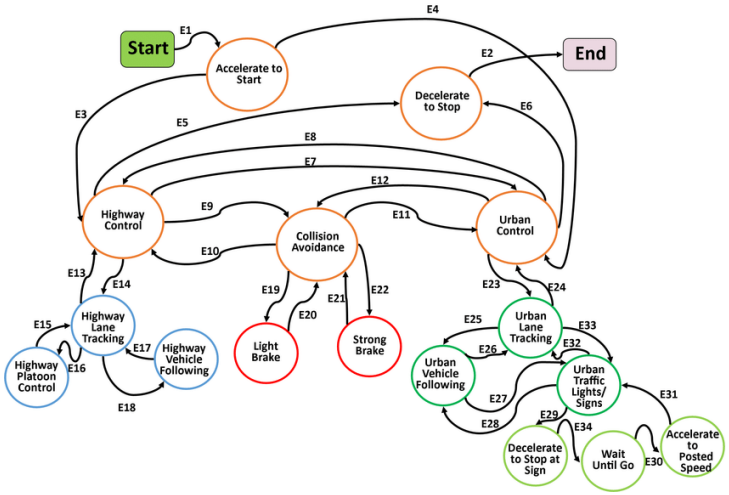
Summary of study activities

- **Ad hoc course:** Strategic Orientation for STEM Research & Writing
- **M.Sc. Course:** Control Systems for Autonomous Ground Vehicles
- **Seminars:** Patent searching best practices with IEEE Xplore, GDPR basics for computer scientists, At the Nexus of Big Data, Machine Intelligence, and Human Cognition, Exploiting Deep Learning and Probabilistic Modeling for Behavior Analytics, Approaches to Graph Machine Learning, Big Data and Computational Linguistics, Risk assessment in real life: experiences from the railway domain

Tactical behavior planning

- **State of the art**: Classical models use manual enumeration of scenarios, as well as listing of off-line evaluated trajectories
- But there are way too many parameters…



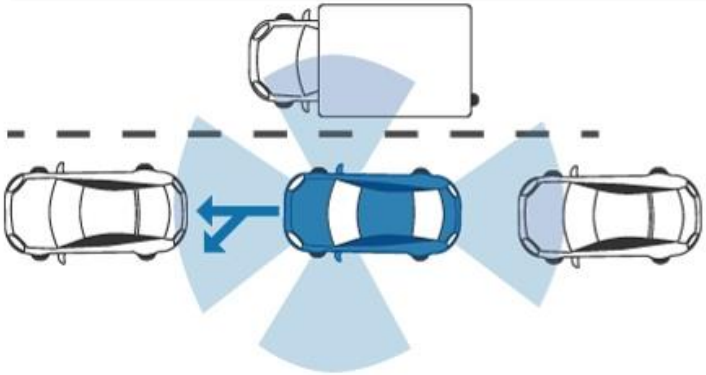


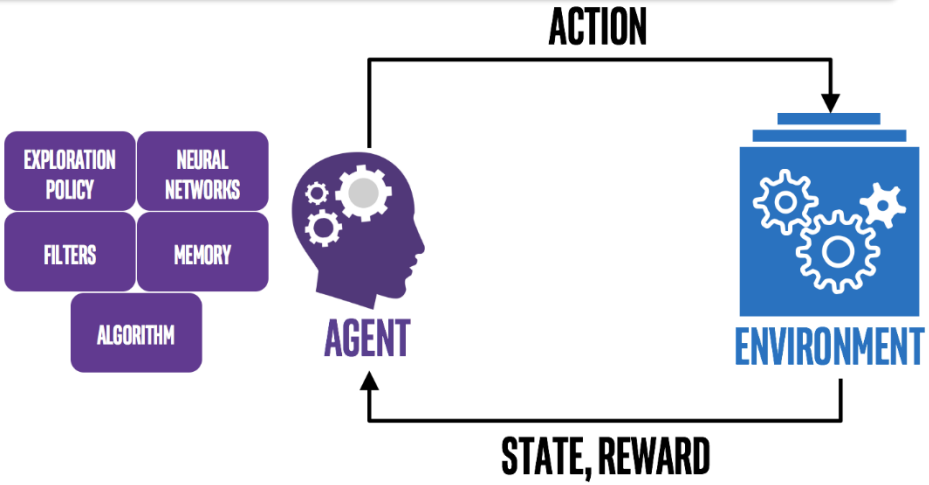
- Every-day driving is too unpredictable, thus making manual behaviors enumeration infeasible
- **Open challenge**: <u>What about learning the parameters?</u>

Deep Reinforcement Learning

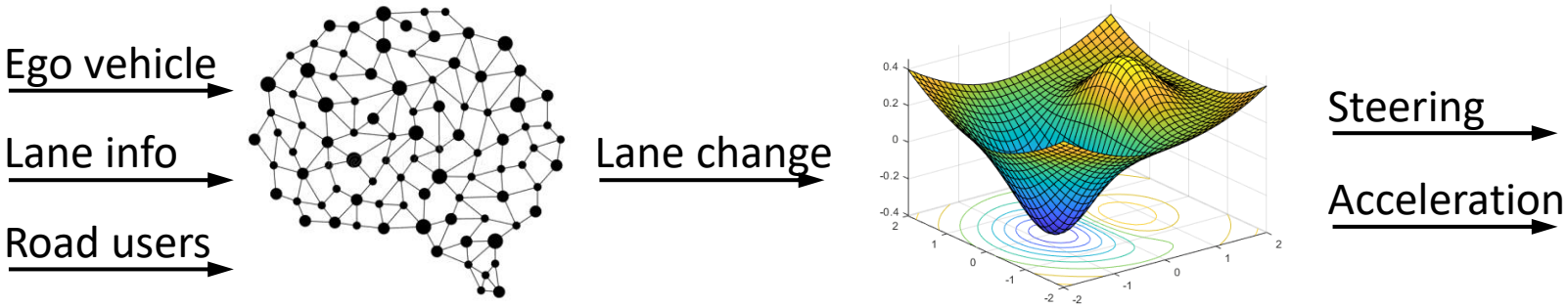
- DRL framework has been proven useful in various field, e.g., playing games, solving continuous control problems etc.
- The planning policy (action) can be directly learnt through interaction between the vehicle (agent) and the road scenario (environment)

- State of the art DRL cannot ensure safety
- The search space (state and action) is way to wide and non-convex (positions, velocities, accelerations, etc.)





Hierarchical Planning on Highways



- The DRL agent (DQN) make only semantically meaningful choices (overtake that vehicle, slow down, give right of way etc…)
- The search space is discrete (and smaller) making the training faster
- A Nonlinear Model Predictive Controller translates the desires in optimal steering and acceleration command. This search space is continuous, one of the state-of-the art algorithm can be used to solve it in real-time, e.g., SQP or IP

Year three: next challenges

- The final PhD year will comprise the analysis of different solutions for the hierarchical planner. The **key challenges** are:
  - Reduce variance during training
  - Increase safety
  - Investigation of complex urban traffic scenarios
- Ideas:
  - Replace the value-based agent (DQN) with a policy-based agent. A policy-based agent does not need the markovian assumption on the environment
  - Define high level of abstraction options graphs tailored to the road scenario. The action is a path on the graph which translates to a behaviour. This approach should increase safety and explainability.

Products

[P1]	*Santini, S.; Albarella, N.; Arricale, V.M.; Brancati, R.; Sakhnevych, A. On-Board Road Friction Estimation Technique for Autonomous Driving Vehicle-Following Maneuvers. Appl. Sci. 2021, 11, 2197. https://doi.org/10.3390/app11052197 (published and indexed SCIE/Scopus)*
[P2]	*Albarella, N.; Masuccio, F.; Novella, L.; Tufo, M.; Fiengo, G. A Forward-Collision Warning System for Electric Vehicles: Experimental Validation in Virtual and Real Environment. Energies 2021, 14, 4872. https://doi.org/10.3390/en14164872 (published and indexed SCIE/Scopus)*
[P3]	*Albarella, N.; Arricale, V.M.; Maiorano, A.; Mosconi, L.; Napolitano Dell'Annunziata, G.; Rocca, E.; Improved Anti-Lock Braking System With Real-Time Friction Detection to Maximize Vehicle Performance, International Design Engineering Technical Conferences & Computers and Information in Engineering Conference 2021 (conference paper publication)*

Thank you for your attention!