UNLV Transportation Research Center Colloquium

Dreams4Cars: EU Horizon 2020 Project: Università degli Studi di Trento

Friday February 15, 2019, 1-4P, TBE-B174

1:00p Learning to Co-Drive: Brain Architectures and Mental Imagery Mechanisms that Help Improving Agents for Automated Driving and Enable Natural Human-Robot Interactions

This talk describes the H2020 Dreams4Cars (D4C) Research and Innovation Action project that deals with the architecture, and the abilities, of agents that should be capable of learning reliable driving and natural human-robot interactions. D4C is not another project for developing automated driving, rather, it is a robotics initiative to develop cognitive abilities that may in turn be used for the development of automated driving. The goals of D4C are 1) automatic discovery of significant situations and 2) automatic learning from those situations. In other words: self-discovery and self-optimisation of behaviour at all levels of sensorimotor control, and including rare events. It also tackles the issue of verifiability of agent learned behaviours (by inspection of the agent's interpretable motor cortex).

The talk will review theories for artificial cognition of embodied robots (robots that have a physical body interacting with the real complex-if-not-impossible to schematise world) and highlight issues that limit the traditional sense-think-act paradigm. Some considerations regarding recent examples of Deep Neural Network implementations (including end-to-end trained networks) that still retain many of the weaknesses of the paradigm will also be given.

I will introduce and motivate a biologically inspired layered control architecture that consists of a network-of-networks (can be implemented with ANNs). I will talk about the large-scale structure of this agent and why it is the multi-loop structure that grants many of the agent's abilities. I will in particular talk about the notion of (artificial) motor cortex and action-selection (in basal ganglia); then moving to the micro-scale structure of these loops and how they also are relevant for the agent's abilities. I will show how the overall agent can be created with use (and re-use) of simple artificial neural networks building components that can be tested in isolation and hence the aggregated behaviour can be certified. I will show examples of emerging safe behaviours that are difficult to obtain with the sense-think-act approach.

I will then focus on the lower levels of sensorimotor control, first taking inspiration from how the human brain efficiently solves the problem of learning the forward and inverse dynamics of its body and of manipulated objects and how these learned models are used for a variety of in-line and offline purposes. I will provide examples of application of these principles to the engineering of artificial agents; in particular examples of vehicle dynamics models learned with artificial neural networks and their use for sensory anticipation, state estimate and motor control.

I will then talk about sensorimotor imagery. Predictions in the brain and neural network architectures for similar efficient prediction in artificial agents. Episodic simulations and embodied simulation. Inline use of sensory anticipation. Forward/inverse model adaptation. Learning efficient motor control at chassis and tactical level. Offline use of sensorimotor imagery. Creating episodes and learning from episodes.

Finally, I will talk about the use of the same agent architecture for creating emergent human-robot interactions (in the "like-me" fashion). I will recall the mirror neuron theory and how mirroring emerges from the agent as just another type of action-selection process. How an agent with mirroring can understand and predict human intentions and how it can collaborate with humans.

Mauro Da Lio received the Laurea degree in mechanical engineering from the University of Padova, Italy, in 1986. He is Full professor of mechanical systems with the University of Trento, Italy. His earlier research activity was on modelling, simulation and optimal control of mechanical multibody systems, in particular vehicle and spacecraft dynamics. More recently his focus shifted to the modelling of human sensory-motor control, in particular drivers and motor impaired people. Prior to his academic career, he worked for an offshore oil research company in underwater robotics (a EUREKA project). He was involved in several EU framework programme 6 and 7 projects (PReVENT, SAFERIDER, interactIVe, VERITAS, AdaptIVe, and No-Tremor). He is currently the coordinator of the EU Horizon 2020 Dreams4Cars Research and Innovation Action: a collaborative project in the Robotics domain which aims at increasing the cognition abilities of artificial driving agents by means of offline simulation mechanisms broadly inspired to the human dream state.

2:30p Mental Imagery for Intelligent Vehicles

The research in the design of self-driving vehicles has been boosted, in the last decades, by the developments in the fields of artificial intelligence. Despite the growing number of industrial and research initiatives aimed at implementing autonomous driving, none of them can claim, yet, to have reached the same driving performance of a human driver. Such considerations lead to reflect on why the human brain is so efficient in solving the driving task, and if it is possible to take inspiration from the mechanisms whereby the brain learns to perform such a complex task. We will try to build upon the reasons why the human brain is so effective in learning tasks as complex as the one of driving, borrowing explanations from the most established theories on sensorimotor learning in the field of cognitive neuro-science. In this direction, we consider the Convergence-Divergence Zones (CDZs) architecture of the cortical sensorimotor loop as the most prominent proposal in explaining the simulation process underlying the human sensorimotor learning. We propose to use the CDZs as a "template" for the implementation of neural network models mimicking the phenomenon of mental imagery, which is considered to be at the heart of the human ability to perform sophisticated sensorimotor controls such driving. In this presentation we will show how this hypothesis can be considered as a starting point for the development of a novel neural network architecture, and will present the results of applying our autoencoder-like ANN to a simulated driving environment.

Alice Plebe received the BSc degree and the MSc degree in computer science from the University of Catania, Italy, in 2014 and 2016 respectively. In 2017, she won a research scholarship at the Department of Mathematics and Computer Science from the same institution, concerning dynamic modelling of fire hazard in industrial environment. Currently, as a PhD student at the University of Trento, she is mainly working on neural networks for the perception-action aspect of autonomous driving, as part of the Dreams4Cars project. Her research interests include deep learning, evolutionary algorithms for architectural applications, and computer graphics.

3:00p Testing agents and controlling vehicles from simulation to real applications

Validating an autonomous driving agent is a complex multi-step process that requires close collaboration between the software developer and the vehicle manufacturer. The purpose of this talk, is to introduce the audience to a common workflow among industries and research institutes to efficiently deploy custom software (both on the vehicle control side and on the higher-level autonomous driving side) also adopted in the H2020 Dreams4Cars research project. The first step is the setup of a Model-in-the-Loop (MIL) environment. In MIL, all the building blocks of the software architecture run in a simulated environment thus neglecting real-time constraints, sensor noise and the inherent stochastic nature of a real road environment. Once the functioning of the software has been thoroughly tested in such an environment, the next step is to move the newly de-signed modules to the specific hardware for the vehicle implementation to fulfill the Software-in-the-Loop (SIL) environment. Be-fore the actual vehicle deployment, a third step is the set-up of a real-time machine capable of generating CAN messages as found in the car, also known as Hardware-in-the-Loop (HIL) test bench. The presentation will also propose two simulation environments (IPG CarMaker and OpenDS) and their use in the context of the described workflow. Finally, a new neural-network based approach to the vehicle control which tries to overcome traditional model-based controller will be presented.

Riccardo Donà is a PhD student working on the EU project Dreams4Cars at the University of Trento, Italy. He obtained the MSc in Mechatronics Engineering cum laude at the same university in 2017. His main scientific interest is in new approaches to vehicle automation and vehicle control which constitutes the core activity of his PhD project.