Dream-like simulation abilities for automated cars

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Executive Summary

This deliverable 6.4 provides evidence about the workshops the project has organised as part of the dissemination and communication strategy. These workshops have been organised in the form of special sessions within larger conferences or as stand-alone workshop addressing a certain community.

This report covers the first 24 Months of project lifetime. During this period one workshop has been organised at Intelligent Vehicle Symposium IV 2017 on 14th June 2017. Another workshop has been held in cooperation with SAFER – Vehicle and Traffic Safety Centre at Chalmers University on 26th January 2018

The planning and organisation for a third event in the context of Intelligent Vehicle Symposium IV 2019 in Paris in June 2019 started.

Further workshops might be organized in the next year.

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1 Background and motivation

Within the Dissemination and Communication Plan (D2.1) Dreams4Cars highlighted the importance of Dissemination. Workshops are an important means to get into contact with target audiences.

Dreams4Cars is working to stimulate or contribute to achieving a breakthrough innovation in cognition abilities of the automated vehicles, to make automated driving reach a high safety standard. To make this contribution as efficient as possible and get it accepted by the scientific community and automotive industry communication with related projects and initiatives is essential for the success of Dreams4Cars.

Beyond attending conferences and workshops and promoting Dreams4Cars the organisation of a number of own workshops have been organised or are planned.

This report depicts our efforts in the context of three workshops

2 Workshop at Intelligent Vehicle Symposium IV 2017

The Intelligent Vehicles Symposium is a yearly event sponsored by the IEEE Intelligent Transportation Systems Society (ITSS). The IV'17 took place from 11-14th June 2017 in Redondo Beach, California, USA. Within this event Dreams4Cars has organised the workshop "Cognitively Inspired Intelligent Vehicles". The workshop took place on 14th June 2017.

Scope of the workshop

The initial focus of a research field interested in the development of autonomous systems is often on algorithms designed from a pure engineering perspective. Research on intelligent vehicles, for example, is currently in this stage. At the same time, there are other fields interested in autonomous systems that have been in existence for longer. One clear example is research on (cognitive) robotics and artificial cognitive systems. A lesson that can be learned from these fields is that the initial engineering-centric methods are eventually supplemented with inspiration from the cognitive sciences. These supplements bring new ways to increase the autonomy of a system, to ensure its ability to deal with events that are not foreseeable at design time, and sometimes even to ensure behaviour that is intuitively understandable by humans that interact with these systems. Conversely, an autonomous system (whether a robot or a vehicle) will necessarily have to interact with humans (in the case of intelligent vehicles, these include the passengers inside the vehicle, pedestrians, other vulnerable road users, and drivers of vehicles that are not automated). The vehicle must therefore also be able to understand and predict the actions of others. Overall, such cognitively inspired approaches are now well established in robotics, both at the control level, and where interaction with human users is concerned, but are only beginning to emerge in intelligent vehicle development. The purpose of the present workshop is therefore to give a forum to researchers who either apply cognitive approaches to intelligent vehicles, or have made major contributions to robotics in this manner. The content of this workshop is thus relevant to anyone interested in one of the major under researched areas in the field of intelligent vehicles, now ripe for exploitation.

Agenda

Time	Title	Presenter
08:30 – 09:00	Cognitive Robotics as an inspiration for Cognitive Vehicles (and vice versa)	Serge Thill, Plymouth University / University of Skövde
09:00 – 10:00	Cognitively inspired User Modelling for enhanced Human-Vehicle interaction	Invited Keynote: Yannis Demiris Imperial College London
10:00 – 10:30		Break
10:30 – 11:10	Using higher-level cognition and simulation as inspiration for intelligent vehicles.	Henrik Svensson University of Skövde
11:10 – 11:50	Biologically inspired decision making for automated driving algorithms	Alex Blenkinsop University of Sheffield
11:50 – 12:30	Artificial drivers technologies for future Intelligent Vehicles and Transportation Systems	Mauro da Lio University of Trento
12:30 – 13:30		Lunch
13:30 – 14:10	Hierarchical Perception Action learning for Cognitive Driver Assistance	David Windridge Middlesex University
14:10 – 14:50	Communicating intent for seamless interaction with automated vehicles	Jonas Andersson RISE Viktoria
14:50 – 15:20	Concept of a Cognitively-Inspired Distributed Data Processing Approach in Automotion and Its Evaluation Framework	Tim Tidemann University of Applied Sciences Hamburg -
16:00 – 16:40	Autonomous but cognitively inspired: the EU project AUTOMATE approach to vehicular automation	Roberto Montanari Re:Lab s.r.l.
16:40 – 17:00		Wrap-up & Conclusions

Further details on the content of the workshop are compiled in Annex 1

3 Workshop at SAFER Vehicle and Traffic Safety Centre at Chalmers

Dreams4Cars joined forces with SAFER - Vehicle and Traffic Safety Centre at Chalmers.

SAFER Vehicle and Traffic Safety Centre at Chalmers is a competence centre where 37 partners from the Swedish industry, academia and authorities co-operate to make a centre of excellence within the field of vehicle and traffic safety. SAFER is an open innovation arena where partners from the society, the academy and the industry can meet and share research and knowledge within safe mobility – a multi-disciplinary research hub that enables progress for its partners and for the society.

Dreams4Cars held a workshop on cognitive systems in autonomous vehicles on 26th January 2018 in Gothenborg, Sweden.

Scope of the workshop

The aim of the workshop was to exchange views on autonomous driving and on cooperation with SAFER and their partnership. SAFER started the workshop introducing the QUADRAE project “Quantitative Driver Behaviour Modelling for Active Safety Assessment Expansion” followed by a presentation on the processing framework to predict driver’s behaviour in automated driving. The session closed with the presentation of preliminary results and a discussion. The second session was devoted to several aspects of the Dreams4Cars project focussing on the artificial cognitive system architecture, the discovery of threatening situations as well as on behaviour optimisation. Finally, the OpenDs environment that is used within Dreams4Cars for simulation has been presented.

Agenda

Time	Title	Presenter
8:15 – 8:30	Introduction about QUADRAE project	Giulio Piccinini (Chalmers)
8:30 – 9:00	Predictive processing framework for modelling driver’s behavior in automated driving	Jonas Bärgman (Chalmers)
9:00 – 9:30	Preliminary results about modelling driver’s behavior as a function of kinematic criticality and automation level	Giulio Piccinini and Esko Lehtonen (Chalmers)
9:30 – 10:00	Break	
10:00 – 10:30	Driver models in safety benefit simulations	Fredrik Granum (Volvo Cars)
10:30 – 12:00	Artificial Cognitive System Architectures for long-term reliable automated driving	Mauro Da Lio (University of Trento)
12:00 – 13:00	Lunch	
13:00 – 13:30	Active discovery of threatening situations by dream-like simulations	Henrik Svensson (University of Skövde)
13:30 – 14:00	Behaviour optimisation and generation of training examples with offline Optimal Control	Francesco Biral (University of Trento)
14:00 – 14:30	OpenDS environment for simulations and dreaming	Rafael Math (DFKI)
14:30 – 15:30	Open discussion	

Further details on the content of the workshop are compiled in Annex 1

4 Workshop at Intelligent Vehicle Symposium IV 2019

The following workshop at IV 2019 has been accepted.

Scope of the workshop

IEEE IV 2019 BROAD Workshop: the BROAD workshop – BRoad and Open-minded discussions of Autonomous Driving

What are the new frontiers of autonomous driving: Are there open technical or non-technical issues that impede autonomous driving now or in the upcoming future? Can cognitive inspiration and machine learning (ML) help us here or do these approaches lead to new problems?

The workshop is structured in two sessions to focus on two major aspects of these questions. The first session will identify major challenges across all aspects of autonomous driving (algorithmic, societal, etc.) that are supposed to or that could probably impede the development of autonomous driving (AD) or its introduction on the market. These could be technical issues (how many test miles need to be driven? is ML reliable? how to select training data?). But these could also be non-technical questions like law-, insurance-related, or ethical questions. Therefore, two different keynotes will be given: one OEM (Mercedes-Benz USA) and one legal scientist (Leibniz University, Germany).

In the second session, cognitively-inspired and ML-based solutions will be presented. Here, we will focus on two approaches: pure ML, and bio-inspired approaches that try to mimic cognitive mechanisms observed in humans and/or animals in a reasonable amount of detail. Each approach has their own particular advantages and limitations. For example, pure ML often requires large amounts of training data, yet is typically very brittle while bio-inspired approaches are by necessity based on incomplete theories, and we’re still missing convincing demonstrations in real applications.

The chairs of the workshop are

- Tim Tiedemann:
  Affiliation: Department of Computer Science, Faculty TI, University of Applied Sciences Hamburg
  Email address: Tim.Tiedemann@haw-hamburg.de
- Serge Thill (Dreams4Cars):
  Affiliation: Interaction Lab, School of Informatics, University of Skövde, Sweden and Donders Institute for Brain, Cognition, and Behaviour, Radboud University, The Netherlands
- Sean Anderson (Dreams4Cars):
  Affiliation: Department of Automatic Control and Systems Engineering, University of Sheffield

Annex 1 – Addition information Workshop IV 2017

Abstracts

Henrik Svensson:

The paradigm of embodied cognition in cognitive science emphasizes the embodied and action-oriented nature of cognition, but some embodied cognition theories also explain the nature of higher-level cognition in terms of embodied interaction. According to the simulation hypothesis, higher-level cognition can be explained as reactivation, i.e., the brain reactivates itself as if it actually were actively controlling the body. In particular, predictive chains of simulated perceptions and actions can be reactivated internally by our nervous system and used in situations calling for representations of the future, especially alternative futures. Our and others research shows that it is possible but not trivial to develop these kinds of predictive chains of simulated perceptions and actions in simple wheeled robots. Simulations in this sense, could be used, not only in simple robots, but in more advanced types of vehicles such as cars, trucks, buses and construction machines whose environment and tasks is likely to call for more advanced mechanisms to cope with all the types of traffic situations that a human driver can. While it is not given that biological inspiration leads to the best technological solutions, this presentation describes the simulation hypothesis and outlines possible ways in which simulation theory and higher-level cognition could be used for developing mechanisms for intelligent vehicles. A brief aside also discusses the so-called anti-representationalist debate in embodied cognition and possible implications for the development of intelligent vehicles.

Mauro da Lio:

This talk will introduce the notion of artificial co-drivers. It will start with an early problem, more than 20 years ago, which was assessing the maneuverability of unstable vehicles (motorcycles) which was solved by simulating these vehicles as if they were “optimally” driven by a sort of imaginary perfect test driver. This lead to the not surprising discovery that minimum time optimal control matches the way trained race drivers actually drive, hence introducing the notion of optimal driving agents.

The talk will then shift to the problem of modeling which optimality criterion holds for ordinary drivers, introducing some theories about optimality of human control (in particular minimum jerk). It will show the use of Optimal Control to model “ideal” ordinary drivers and its application to produce “reference maneuvers” used as gold standard in Advanced Driver Assistance Systems. In particular, the application of these ideas in the PReVENT project (2007) will be presented.

The problem of modelling human driver behavior when multiple choices are possible, is then considered, reviewing the Simulation Hypothesis of Cognition and its implication for the inference of intentions of drivers (a process that in natural cognition is called mirroring – from mirror neuron theory – and which can also be considered as the “mother nature” version of model-based state estimation). The application of this mechanism in the EU InteractIVe project will be presented, showing how this mechanism naturally leads to a topographic representation of possible actions, which has direct analogies with the human motor cortex. Based on this idea, an architecture that simulates human layered control (with action selection) will be presented and, it will be shown how the mirroring process can be implemented with a particular type of action-selection mechanism. Hence the same sensorimotor system can be used to engineer an agent that drives autonomously or that understands the intentions of the human driver and cooperates in the driving tasks. In the conclusions, the potential impacts of the reviewed technologies will be examined.

David Windridge:

Perception-Action (P-A) learning is an approach to cognitive system building that seeks to reduce the complexity associated with conventional environment-representation/action-planning approaches. Instead, actions are directly mapped onto the perceptual transitions that they bring about, eliminating the need for intermediate representation and significantly reducing training requirements.

Subsumptive P–A models capture the hierarchical nature of the task structuring implicit in human agents and further assume a parallel hierarchical structuring within the agent's perceptual domain. In the context of an intelligent driver assistance system, adopting this model enables us to characterize intentions at each level of the P–A hierarchy in terms of perceptual descriptors correlated with driver behavior. A key problem in the context is reconciling high-level protocols (i.e., Highway Code rules) with low-level perceptual features; we here set out a general approach to the integration of abstract symbolic manipulation into P-A learning.

Jonas Andersson:

Mutual understanding and trust between automated vehicles and their occupants, as well as between automated vehicles and other road users in their vicinity, such as pedestrians and bicyclists, are two cornerstones for seamless and safe interactions in our traffic. This presentation highlights the importance of clear communication among all involved parties, both inside and outside vehicles, for creating such interactions. In particular, it presents a series of studies conducted by RISE Viktoria and partners in Sweden, where it is hypothesized that communicating own intent makes it easier for automated vehicles and humans to predict and understand each other's behavior and to act accordingly. This is explored in different contexts using both interior and exterior vehicle interfaces for intent communication.

Roberto Montanari:

In autonomous systems, a human-like understanding of environment, as well as mutual comprehension between drivers and machine, is expected to significantly improve a seamless and effective transition in vehicle controls, rightly allocating the driving task to the agents (no matter if human or machine) most suitable and reliable at each moment. The steps to reach this ambitious goal are in the scope of AUTOMATE project, and mostly in the part dedicated to the Human Machine Interface design, one of the cores of this EU funded project within the umbrella of Horizon 2020. This presentation will give an overview of the project's current work, focusing the attention on the paradigms adopted in machine learning techniques framework, in human factors and in HMI design.


Our Continuous (lifelong) Interactive Learning Cycle
2. Use machine learning algorithms to build hierarchical user models
3. Predict required levels of assistance / collaborative control

Annex 2 - Addition information Workshop SAFER

Abstracts

Mauro Da Lio, University of Trento

Artificial Cognitive System Architectures for long-term reliable automated driving

Automated driving will need unprecedented levels of autonomy, reliability and safety for market deployment. The average human-driver fatal accident rate is approximately 1 (fatality) every 100 million miles in the US and the EU. Hence, automated vehicles will have to provably, and significantly, best these figures. Unfortunately, according to many reports on the disengagements of prototype automated driving systems, today we are far from demonstrating these levels and, even worse, a large amount of resources appear to be still necessary towards achieving this objective.

This talk presents the position of the partners of the H2020 Dreams4Cars research project (a Research and Innovation Action funded under the EU Robotics banner) regarding the architecture, and consequently the abilities, of agents capable of long-term reliable driving.

Today almost all approaches to automated driving implicitly assume the sense-think-act paradigm (aka perception-decision-action). Several examples of such current approaches will be examined. We believe that the agent architecture, implicitly assumed, besides being very hungry in terms of resources for development, is also inadequate to achieve robust autonomy for the same reasons it was unsuccessful in other similar robotic applications. We review several critical aspects of this architecture, from scalability to maintainability and validation; including some considerations regarding recent examples of Deep Neural Network implementations that still retain many of the weaknesses of the paradigm.

Then, I will introduce and motivate a (biologically inspired) layered control architecture that, we believe, can scale much better to deal with the complexity of the real world. I will also describe a learning mechanism similar to human dreams, in which the agent itself can anticipate potential threats and prepare to act in threatening situations before they are even met. This way the agent may become expert (like senior drivers are compared to young drivers) by learning from discovered potential threats. Besides increased autonomy and robustness, this approach looks to be more economical in terms of resources needed for development.

The talk will give many details about implementation of the agent, which uses Deep Neural Networks as building block but writhing a network of networks that reproached the main functionalist of the human brain, including simultaneous affordance generation, episodic simulations, robust adaptive action-selection, sensory anticipation. I will also mention how the similarity of the function implementation may allow to trigger a “mirroring” mechanism with the humans, which makes the agent capable of “understanding” human intentions and being naturally understood by humans (this will be contrasted with the known causes of accidents occurred so far in AD testing).

In the end, recent developments in the Dreams4Cars project will be presented. In particular how to engineer artificial drivers that can learn by rehearsing their own experiences, in a way that is very similar to human dreams.

Henrik Svensson, University of Skövde

Active discovery of threatening situations by dream-like simulations

This talk outlines some of the aspects of the dream-like simulations to be developed within the H2020 Dreams4Cars research project (a Research and Innovation Action funded under the EU Robotics banner).

In this project one aim is to create dream-like simulations, which consists of reconstructions and recombitions of the cars previous experiences into novel situations from which the car gains new knowledge. While dreams in this project are not an exact equivalent of the dreams of biological agents, there are some crucial aspects of "biological dreams" that will be drawn upon in this project: (1) dreams and other kinds of mental simulations are off-line, i.e., they are active but are not interacting with the controlled entity, the extra-neural body in biological agents, in particular (2) dreams reactivate the control system as if it were interacting with the controlled entity. (3) Dreams enable the biological agent to think about previous and future situations to (4) increase its ability to handle situations in the waking state (Svensson, Thill & Ziemke, 2013; Svensson & Thill, 2016).

The talk presents some of the background on biological dreaming and simulation as well as outlines the type of "dreams" that will be used in the project and some more specific details on how we aim to implement the "dreams".

Francesco Biral, University of Trento

Behaviour optimisation and generation of training examples with offline Optimal Control

The majority of modern and state of the art approaches for the development of automated driving heavily rely on artificial intelligence (AI) and on the use of Deep Neural Networks. The AI has to be trained and tested on a large amount of driving data to achieve the reliability and safety level necessary to drive 100 millions mile without a fatal accident. The H2020 Dreams4Cars research project aims at solving this problem using a dream mechanism to teach the agent to become an expert driver by learning from discovered potential critical situations.

This talk presents the approach used in Dreams4Cars to train the agent in the dream state via the use of optimal control techniques to model different driving behaviors. According to experimental evidence, the optimality of human sensorimotor control is constantly assumed in this project and it is used to implement the inverse models (i.e. affordances) that map sensory data with controls.

The layered control architecture of Dreams4Cars, which is biologically inspired by the human brain, foresees the use of three data streams. In particular, the first of stream (dorsal stream) creates an artificial "motor cortex" map, which is a two-dimensional map of the control space (i.e. lateral and longitudinal controls) from perceived sensory data. The value that is encoded in the motor cortex map is called salience (s) of the trajectory/trajectories. The salience originates at each couple of lateral and longitudinal control and expresses "how good" the particular choice of controls is. Points (i.e. controls) that are close in the motor cortex correspond to trajectories aiming at similar, but slightly different, directions in the space. Therefore, different regions in the cortex map correspond to different affordances (e.g., lane change, car follow etc.) which are produced with different (families of) trajectories. The height of each hump in the motor cortex is the urgency of that particular affordance and describes the active regions in the motor cortex.

The talk introduces the formulation of the inverse models as optimal control problems and the numerical approach used in Dreams4Cars to find the optimal solution that generates the optimized behavior in term of motor/salience map and affordances. The talk also discusses computational challenges along with the approach adopted to incorporate the driving style and the characteristics dynamic response of vehicle to driver's inputs. In the end, recent examples from the Dreams4Cars project will be shown.

<u>Raffael Math, DFKI</u>

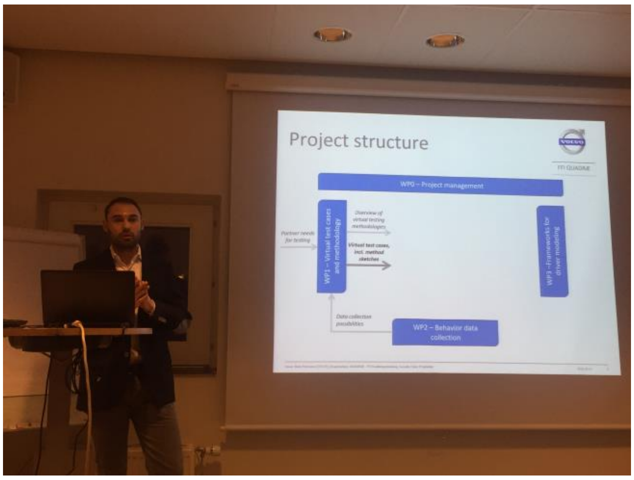
<u>An Open-Source Driving Simulator for Automated Driving</u>

This talk introduces OpenDS, a free driving simulator, which has first been released under open-source license in 2013. As full-fledged driving simulation software for the evaluation of automotive applications is high in price and low-cost simulators often lack of extensibility, OpenDS was initiated to provide a basic simulation toolkit to the researcher community and counts today more than 1500 users from both academia and industry.

OpenDS is implemented in Java and based on the jMonkeyEngine, a high-performance scene graph-based graphics API which uses Bullet for physics simulation. Due to a high number of extensions and a variety of pre-defined driving tasks, many different scenarios can be simulated out-of-the-box or be created with little effort. Moreover, OpenDS is ready to connect to various hardware (eye tracker, CAN bus, motion seat, steering wheel, Oculus Rift) as well as software (traffic light simulation, multi-driver simulation, data and multimedia provider) and supports multi-screen output for surround projection.

The latest development is driven by the H2020 Dreams4Cars research project, where the simulation software will be used to train an artificial driver in a safe environment. By the means of simulation, almost any critical situation which might never appear under real conditions – even after millions of kilometres of driving – can be created, modified, and simulated multiple times.

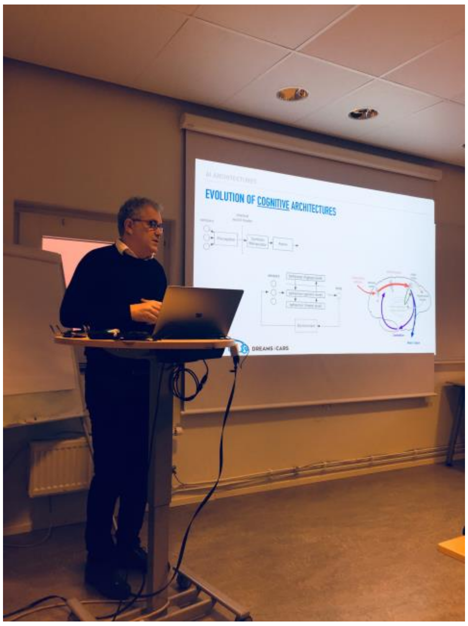
The talk also gives insight in the recent simulation developments of the project, especially into the “dreaming mechanism” where critical scenarios will be generated automatically for subsequent simulation, the integration of an interface to operate the virtual vehicle by the artificial driver, and the integration of Chrono, a more realistic multibody physics engine.




Introduction


ARTIFICIAL COGNITIVE SYSTEM ARCHITECTURES
LONG-TERM RELIABLE AUTOMATED DRIVING


Reactivation in motor imagery


EVOLUTION OF COGNITIVE ARCHITECTURES


Driving simulator study – analysis