Booklet of abstracts

Biagio Ciuffo, Michalis Makridis

The future of road transport and emerging issues from advanced vehicle technologies"

Abstract: A perfect storm of new technologies and new business models is transforming not only our vehicles, but everything about how we get around, and how we live our lives. In our work we look at some main enablers of the transformation of road transport, such as data governance, infrastructures, communication technologies and cyber-security, and legislation. It discusses the potential impacts on the economy, employment and skills, energy use and emissions, the sustainability of raw materials, democracy, privacy and social fairness, as well as on the urban context. It shows how the massive changes on the horizon represent an opportunity to move towards a transport system that is more efficient, safer, less polluting and more accessible to larger parts of society than the current one centred on car ownership. However, new transport technologies, on their own, won't spontaneously make our lives better without upgrading our transport systems and policies to the 21st century. Current evidence for example shows that upcoming technologies such as ACC and other ADAS systems are not evolving in the direction of making road transport more efficient, by increasing the likelihood of traffic instability and by increasing energy consumption from cars by approximately 15%. In this context, the improvement of transport governance and the development of innovative mobility solutions will be crucial to ensure that the future of transport is cleaner and more equitable than its car-centred present.

Martin Treiber

Effects of congestion on fuel consumption and how CAVs can help improve the situation - a simulation-based approach

Abstract: The driving styles of human drivers or connected automated vehicles (CAVs) significantly influence fuel or stored energy consumption and emissions. Besides the direct effect depending, e.g., on the speed and the smoothness of the driving style and the anticipation of the driver or CAV, there are indirect effects on the neighboring vehicles having to react to, e.g., sudden speed changes or abrupt lane-changing maneuvers. Moreover, there is a longer-term indirect effect mediated via congestion and traffic waves by the aggregated traffic-flow efficiency and stability. Finally, closely-spaced CAV platoons result in less consumption per vehicle due to the reduced wind drag. In this contribution, I will simulate these factors using dedicated microscopic models for human drivers and automated unconnected and connected vehicles which are coupled to a physics-based instantaneous modal consumption model that can be applied to internal combustion and electric vehicles. Two CAV cases are considered: platoons on freeways with vehicle-vehicle (V2V) communication, and city traffic with varying percentages of CAVs with vehicle-to-infrastructure (V2I) communication in form of a "traffic-light assistant". It turns out that, in crowded situations, the indirect congestion effects are most prominent and that the percentage fuel savings are about one third of the percentage time savings due to reduced congestion.

Nour-Eddin El Faouzi, Andres Ladino

A Framework of Simulation and Impact Assessment of Connected and Automated Traffic

Abstract: Recent years have seen the development and the emergence of new Cooperative Intelligent Transportation Systems (C-ITS) where data sent via Information and Communication Technologies (ICT) has a potential to enhance traffic conditions instead of extending physical infrastructure, thereby introducing new business models and reduction of environmental impact. These technologies along with the introduction of new features in the Advanced Driver Assistance Systems (ADAS) bring new challenges in terms of evaluation and performance of Connected & Automated Vehicles (CAVs). Key aspects such as policy design, field operational test design, acceptance of the (C-ITS) services and scalability of these services contribute a better assessment for reliability at the implementation tests. This talk provides an overview of general framework to perform the evaluation of new C-ITS by integrating these aspects into a 3 stage framework. An initial proposition of this simulation framework has been introduced via multi-agent systems that integrate interactions of physical, communications, and trust layers when deploying C-ITS services. It concludes by introducing fundamental challenges in terms of new approaches to maintain privacy of users who contribute data for enhancing these services and incentives to achieve better harmonization in between new technologies, C-ITS and their deployment in real scenarios.

Francesco Viti, Marco Rinaldi

Mix Fleet Assignment of Hybrid and Electric Buses with Opportunity Charging

Abstract: In this talk we present a new formulation for single and multiple bus terminals equipped with opportunity charging stations, and a decomposition scheme that allows solving efficiently the problem for large scale instances. A Mixed Integer and Linear Program is presented and its complexity analysed. A demonstration of the validity of the approach is presented using different interconnected lines within the Luxembourg bus network. The study shows how to handle the transition towards full electrification of the network, which is planned in the country for 2035, and how to align bus scheduling with charging constraints. In addition, the presentation is framed within a larger national project (eCoBus) in collaboration with Volvo Bus Corporation among other partners to jointly optimise planning and operational decisions of electrified bus systems.

Javier Alonso-Mora

Predictive routing and multi-objective fleet sizing for shared mobility-on-demand

Abstract: We move towards an era of smart cities, where autonomous cars will provide on-demand transportation while making our roads safer. In this talk I will give an overview of our work in dynamic vehicle routing for large-scale ride-sharing. Firstly, for fleet management, I will describe an anytime optimal method that is capable of online assignment of large numbers of requests to vehicles and routing them accordingly. The proposed framework includes rebalancing of idle vehicles and has been extended towards predictive routing with a model of future demand.

Secondly, I will discuss a multi-objective optimization to trade-off quality of service vs. operation cost.

Julien Monteil

Models of competition and cooperation in ridesourcing mobility

Abstract: The early promises of ridesharing for alleviating congestion in cities may be undermined by a number of challenges, including the growing number of proposed services and the subsequent increasing number of vehicles, as a natural consequence of competition. Here we present optimization-based approaches to model cooperation and competition between multiple ridesourcing companies, in a real-time on-demand setting. A recent trend relies on solving the integrated combination of Dial-A-Ride Problems (DARP), which compute the cost of assigning incoming requests to vehicle routes, plus Linear Assignment Problems (LAP), which assign vehicles to requests. While the DARPs, are solved at the level of the vehicles of each company, we introduce cooperative and competitive approaches to solve the LAP. The cooperative model, which could make use of Mobility as a Service platforms, is shown to solve the LAP to optimality following closely results from the literature, and limiting the amount of information the companies are required to share. We investigate how a realistic model of competition deviates from this optimality and provide worst case bounds. We evaluate these models with respect to a centralized model on one-week instances of the New York City taxi dataset. The computational results suggest that cooperation among ridesourcing companies can be conducted in such a way to limit the degradation of the level of service with respect to a centralized model. Finally, we argue that the competition can lower the quality of the ridesharing service, especially in the case customer preferences are accommodated.

Bin Yang

Learning to Route

Abstract: As part of the continued society-wide digitization, more and more data is becoming available in the form of trajectories that capture the movements of vehicles. This data offers a foundation for improving vehicular transportation, including routing. Learning to route aims at extracting knowledge from trajectory data to enhance routing quality. This talk covers three categories of learning to route techniques: extracting time-varying and uncertain travel costs from trajectories, learning routing preferences from trajectories, and data-intensive routing.

Kanok Boriboonsomsin

Connected Vehicle Routing for Reducing Human Exposure to Traffic-Related Air Pollution

Abstract: The emerging of Connected Vehicle (CV) technology has led to innovations that promise to improve safety, mobility, and sustainability of future transportation systems. Many CV applications have been developed over the last several years that target specific benefits such as avoiding vehicle crashes, reducing travel delays, and lowering greenhouse gas emissions. To date, there has been

much less attention on utilizing CV technology to reduce criteria pollutant emissions from vehicular traffic, and even less so on using it to reduce human exposure to these pollutant emissions. Heavy-duty diesel trucks (HDDTs), the majority of which are used for freight movement, are significant contributors of nitrogen oxides (NOx) and fine particle (PM2.5) emissions. As a result, communities close to freight hubs such as seaports, railyards, and distribution centers often experience elevated levels of diesel-related air pollution. There has been increasing awareness of this environmental justice issue, where residents in these communities bear most of the air pollution and public health burdens generated by these trucks.
In this study, we develop a new CV application specifically designed to reduce the environmental and health impacts of traffic-related pollutant emissions. The application aims to direct highly polluting vehicles such as HDDTs onto a route that would reduce the exposure of local residents to the harmful pollutant emissions generated by these vehicles without significantly increasing their travel distance and travel time. The underlying algorithm uses information about roadway, traffic, and weather conditions as well as the spatial distribution of local population and the locations of sensitive facilities (e.g., schools, daycare centers, hospitals) in the calculation of the suggested route. The simulation of the application for 1,276 HDDT trips in a Southern California city shows that a low exposure route that is different from the shortest distance route can be found for 901 of the trips (71%). For these trips on average, the low exposure route has 5% longer distance but would reduce the total exposure of local residents to both PM2.5 and NOx emissions by 75%.

Giovanni De Nunzio

Electric vehicles driving range maximization via eco-routing, eco-driving, and energy consumption prediction

Abstract: Driving range is one of the main obstacles to the wide diffusion of electric vehicles. In order to overcome it without needing to increase battery size and price of the vehicle, one promising solution consists in leveraging advanced driver assistance systems (ADAS) to increase and master the driving range. This work proposes model-based strategies to predict and optimize the energy consumption of a trip. Before the trip an energy efficient route is suggested. During the trip a precise prediction of the current driving range is provided, and an optimal speed profile is computed to advise the driver. These strategies take into account the specific vehicle parameters, as well as the topology of the road network in which the vehicle operates, and the real-time traffic conditions. A macroscopic version of the energy consumption model of the electric vehicle is presented in order to use the aggregated real-time data available on typical maps web-services. The road network is modeled as a weighted directed graph adapted to the proposed energy consumption model. The energy driving range and the optimal route are finally obtained by means of a suitable optimal path search algorithm. For eco-driving, a different approach using an artificial neural network (ANN) has been chosen to enable real-time implementation. As for the human-machine interface (HMI), the output of these strategies is finally suggested to the driver via a smartphone application. Experimental results show promising gains as compared to the existing approaches in predicting vehicle energy consumption, in suggesting an efficient route, and in providing eco-driving assistance.

Hesham Rakha

Leveraging Connected Automated Vehicles to Reduce Transportation System Energy/Fuel Consumption

Abstract: The transportation sector consumes around 100 quadrillion BTUs of energy worldwide, which is mostly petroleum-based products including gasoline and diesel fuels. More than 7 gigatonnes of CO2 emissions are also attributed to the transportation sector, and represent about 20% of the total CO2 emissions from fuel combustion. However, it would be difficult to imagine our modern life without motorized transportation. Alternative transportation energy sources such as hybrid-electric and electric technologies, bio-ethanol, and hydrogen fuel cells are emerging and are being broadly investigated as replacements for the conventional internal combustion engine. However, these new alternatives have not been able to replace petroleum-powered engines because of challenges that relate to availability, cost, convenience, lack of technology, and accessibility. Consequently, there is a need to improve the efficiency of travel in urban and rural areas. One of the key strategies to improving vehicle fuel efficiency is obtaining more miles from each liter or gallon of fuel. The presentation will highlight the research at the Center for Sustainable Mobility (CSM) at Virginia Tech on developing a novel Eco-Cooperative Adaptive Control (Eco-CAC) system. This system consists of a bi-level controller. At the upper level an eco-router and strategic speed controller ensures that vehicles are routed and driven in an energy-efficient manner. At the lower level a Cooperative Adaptive Cruise Control system ensures that vehicle trajectories are optimized to minimize vehicle energy consumption on freeways and signalized arterials.

Silvia Siri, Simona Sacone

Traffic control for sustainable freeway networks

Abstract: Aspects related to sustainability are becoming more and more relevant in the design and control of mobility and traffic systems. Different definitions of sustainability have been provided in the last decades, all based on the idea that the present actions should be beneficial for the humans and the environment of both the present and the future society. In the area of traffic systems, the main sustainability-related aspects that are explicitly considered refer to pollutant emissions, fuel consumptions, and accidents. Their reduction is a control objective to be pursued by traffic controllers, often considered together with the more “classical” goal of traffic control, i.e. the minimization of traffic congestion or maximization of traffic throughput. This presentation will provide an overview of many research works on freeway traffic control including sustainable-related objectives, starting from simple feedback strategies and moving towards more complex control schemes (predictive schemes, supervisory frameworks, and so on). Particular attention will be also paid on multi-class traffic controllers in which different classes of vehicles are explicitly considered and dedicated control actions are determined for each class. The presentation will also provide some insights on present and future research challenges for sustainable freeway traffic control, considering the innovation brought by the emerging information and communication technologies, with specific reference to connected and automated vehicles.

Maria Laura Delle Monache

Traffic flow implications of autonomous and partially autonomous vehicles

Abstract: It is anticipated that in the near future, the penetration rate of vehicles with some autonomous capabilities (e.g., adaptive cruise control, lane following, full automation, etc.) will increase on roadways. This talk will show the potential impact on traffic of these automation systems. In particular, we will focus on the potential to control automated vehicles to stabilize traffic flow and reduce traffic emissions. Even when deployed at low penetration rates, it is possible to use automated vehicles to eliminate human-generated phantom traffic jams that seemingly occur without cause. We will show how vehicle emissions of the entire fleet may be reduced when stop-and-go waves are dissipated or eliminated by the dampening action of the autonomous vehicle in the flow of human drivers. This is possible if a small fraction (~5%) of vehicles are autonomous and designed to actively dampen traffic waves. The talk will also highlight new findings about the traffic impacts of current, commercially available level-one automated vehicle systems already on the road.

Gabor Orosz

Improving the energy efficiency of road transportation with connectivity and automation

Abstract: In this talk I discuss the potential benefits of connected and automated vehicles on the energy efficiency of ground transportation. In particular, I focus on the longitudinal control of automated automobiles and heavy duty trucks that utilize information obtained by sensors and wireless vehicle-to-everything (V2X) communication. It is demonstrated that by optimizing these controllers at multiple time and spatial scales allows one to reduce the energy consumption of connected automated vehicles without compromising safety or driver/passenger comfort. Moreover, it will be shown that these vehicles can have a positive impact on traffic dynamics and they can improve the energy efficiency of the overall transportation system by mitigating congestion waves. The theoretical results are demonstrated by numerical simulations and verified by experiments.

Meng Wang

Platooning and cooperative driving at freeway merges: impact on traffic flow and model based design

Abstract: In this presentation, recent advances in modeling and design of cooperative driving systems will be discussed. Simulation based impact assessment of CACC with control authority transition between human driver and automation on traffic flow characteristics will be presented. The insights into the impact of CACC systems on traffic flow shed lights on designing cooperative merging systems. We then propose a hierarchical model-based framework to optimize merging sequence, lane change time and location to maximize efficiency, safety and comfort. The performance of the framework is demonstrated in simulation.

Karl H. Johansson

Automated heavy-duty vehicle platooning and its influence on traffic

Abstract: Automated and connected road vehicles enable large-scale control and optimisation of the transport system with the potential to radically improve energy efficiency, decrease the environmental footprint, and enhance safety. In this talk we will focus on automated heavy-duty vehicle platooning, which is currently being implemented and evaluated by several truck manufacturers world-wide. We will discuss how to deploy feedback control of individual platoons utilising the cellular communication infrastructure and how such controlled platoons can be used improve overall traffic conditions. It will be argued that the average total variation of traffic density can be reduced and thereby creating incentives for platooning beyond fuel savings and driver support.

Lars Eriksson

Connectivity and planning as enablers for optimal control of commercial vehicles

Abstract: The connectivity and availability to future driving information gives many opportunities for planning that can utilize the system components in an optimal manner. This is especially true for systems that have many degrees of freedom, like hybrid vehicles. When the future knowledge is available from the connectivity mechanisms and planning algorithms the question arises: How can we use this information? This question can be addressed with the aid of optimal control and this presentation focuses on key results from the area of optimal control of vehicles and focuses on their use in commercial vehicles. Historical results on planning of vehicle driving are summarized and their implications on current commercial vehicles are highlighted. Optimal control results for both on and off-road vehicles will be covered. In addition, some recent results will be discussed related to optimal control of thermal dynamics of diesel after-treatment systems in hybrid vehicles, connected to the impact that all-electric driving in zero emission zones can have on fuel economy and emissions.

Ardalan Vahidi

Anticipative Guidance of Connected and Autonomous Cars for Energy Efficiency

Abstract: Connected and automated vehicles (CAV) are marketed for their increased safety, driving comfort, and time saving potential. With much easier access to information, increased processing power, and precision control, they also offer unprecedented opportunities for energy efficient driving. This talk highlights the energy saving potential of connected and automated vehicles based on first principles of motion, optimal control theory, and practical examples from our previous and ongoing research. Connectivity to other vehicles and infrastructure allows better anticipation of upcoming events, such as hills, curves, slow traffic, state of traffic signals, and movement of neighboring vehicles. Automation allows vehicles to adjust their motion more precisely in anticipation of upcoming events, and save energy. Opportunities for cooperative driving could further increase energy efficiency of a group of vehicles by allowing them to move in a coordinated

manner. Energy efficient motion of connected and automated vehicles could have a harmonizing effect on mixed traffic, leading to additional energy savings for neighboring vehicles. We present analytical and experimental results from a US DOE funded project in which we are exploring the impact of anticipative vehicle guidance on energy efficiency of CAVs and surrounding traffic. The benefits are shown in simulated scenarios and also in a novel vehicle-in-the-loop experiment on a test track.

M.C.F. Donkers

Complete Vehicle Energy Management with Eco-Driving

Abstract: In this talk, I will discuss the concept of complete vehicle energy management (CVEM). In CVEM, the objective is to optimize energy consumption of a vehicle, by optimizing the power flows of all the subsystems, including the vehicle's auxiliary systems (such as the HVAC system). The method uses distributed static optimization, which makes the method scalable (in the number of components and the time horizon) and reconfigurable (meaning that components can be easily added/removed from the vehicle's topology). The CVEM is framework is powerful and versatile and I will show that eco-driving, in which the vehicle's velocity profile is optimized, can be easily added to optimization framework. It will also be shown that the problem has a unique solution, in spite of the fact that it leads to a nonconvex optimization problem. Finally, some experimental results with eco-driving on a fully electric city bus will be presented.

Dominik Karbowski

Powertrain-specific optimal eco-driving control for connected and automated vehicles

Automated driving presents a new opportunity for improving vehicle energy efficiency. Thanks to high-definition maps, perception sensors, sensor fusion, recognition algorithms and V2X communications, the vehicle is gaining a new level of intelligence about its surrounding environment. The vehicle controller can then apply that knowledge towards adapting the speed and powertrain operations to improve the overall vehicle energy-efficiency. We present here the development of powertrain-specific eco-driving controllers for electric, conventional and hybrid electric vehicles, based on optimal control theory. In order to make them implementable in real-world vehicles, we adapted the theoretical formulation derived from the Pontryagin minimum principle to work with a receding horizon. This allows frequent updating of the optimization based on state feedback and new information about the future. The controllers interact in simulation with detailed dynamic models of the powertrain to ensure accurate estimation of the energy impacts.

M.A.S. Kamal

An Efficient Driving Scheme for a Partially Connected Vehicle Environment for Improving Traffic Performance

Abstract: This talk will address a partially connected vehicle environment (PCVE), where only a fraction of vehicles is equipped with V2V communication devices and broadcast their state information, and present an efficient driving scheme for an automated vehicle. Specifically, efficient driving scheme uses a model predictive control framework that needs to predict the preceding traffic in a finite horizon. For acquiring the traffic conditions on the preceding road segment, a road-speed profile (RSP) is proposed, which is dynamically updated using limited V2V traffic data. The RSP is then used to predict the future states of the preceding vehicle, and an optimization problem is solved to determine the vehicle control input. Both the RSP and performance of vehicles under the scheme are evaluated through simulation.

Luigi Del Re

Optimal vehicle operation under traffic conditions

Abstract: Methods for off-line computation of optimal vehicle control on a given route are well known and even commercially available. In practice, however, the actual traffic and environment conditions will force to deviate from the ideal operation profile. In this presentation we first look at the question starting from the top, e.g. a classic eco-driving problem, to see how real traffic induced changes not only affect the actual performance but also the tradeoff between different quantities, e.g. consumption and emissions. Ways to describe traffic as stochastic models are presented as well. Then we look at the same question from the bottom, discussing the use of local ADAS with the same cost factors of the original eco-driving problem, but at microscopic level, to approximate the same result. Finally, we present an outlook, in particular the inclusion of V2X communication as the TLA case, and its expected impact on the cost functions.