Fernando Garcia Fernandez and Zhixiong Li

EDITOR'S NOTE

Please send details of your PhD/MPhil thesis to the Column Editors by contacting them via Fernando Garcia Fernandez at fegarcia@ing.uc3m.es and/or Zhixiong Li at zhixiong.li@ieee.org

Efficient Predictive Model-Based and Fuzzy Control for Green Urban Mobility

Anahita Jamshidnejad

Abstract

This thesis develops efficient model-predictive control (MPC) and model-based fuzzy control methods, as well as accurate and fast modeling and estimation approaches for urban traffic networks. The thesis includes three main parts:

- In the first part, the main focus is on accurate microscopic approaches for estimating the macroscopic traffic variables, i.e., temporal-spatial flow, density, and average speed.
- The second part includes efficient approaches for solving the optimization problem of the nonlinear MPC-based controller for urban traffic networks.
- The third part proposes an adaptive and predictive model-based type-2 fuzzy control scheme that can be implemented within a multi-agent control architecture.

Flow and density are used to partly characterize the state of the physical systems with moving particles, such as traffic networks. These average variables may be defined as temporal, spatial, or temporal-spatial. Computation of the first two averages is straightforward, while details regarding computation of the temporal-spatial variables are missing in literature. Developing accurate and fast estimation approaches for these variables has been addressed in the first part of the thesis.

Next, general smoothening approaches are developed to readjust nonsmooth MPC optimization problems into smooth ones, which can be solved by efficient gradient-based optimization methods. The resulting smooth MPC-based controller is applied to an urban traffic network to find a balanced trade-off between prevention/reduction of traffic congestion and decreasing the level of emitted pollutants. Additionally, a general framework is developed to integrate and interface macroscopic traffic flow models and microscopic emission models, resulting in a computationally efficient and accurate mesoscopic traffic flow and emission model.

In the third part, predictive and model-based control methods are combined with intelligent control approaches, which have a low computation time. The resulting two-layer adaptive control system, with an MPC-based controller in the top layer and fuzzy controllers in the bottom layer, can be used in a coordinative multi-agent control architecture.

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Integrated Capacity Assessment and Timetabling Models for Dense Railway Networks

Nikola Bešinović

Abstract

Mainline railways in Europe are experiencing increasing use as the worldwide demand for passenger and freight transport is growing across all transport modes. At the same time, much of the existing railway network is reaching its capacity and has become susceptible to disturbances.

This thesis creates, optimizes, and evaluates railway timetables to promote more reliable, attractive and sustainable railway transport systems. We develop an integrated approach for improved railway timetabling that combines capacity assessment and scheduling models in order to design timetables that are efficient, i.e., have as short as possible journey times, feasible, i.e., all trains operate undisturbed by other traffic, stable, i.e., do not have excessive infrastructure capacity occupation, and robust, i.e., able to mitigate certain everyday operational disturbances.

The proposed modular multi-level performance-based framework includes macroscopic and microscopic models and necessary transformations between them. A macroscopic optimization model is used to solve timetabling problems for complex, large and dense railway networks. To obtain also robust solutions, while maintaining a good trade-off between efficiency and robustness, timetables are tested with stochastic simulations. Microscopic computation of running times using Newton motion formulae generate the input to macroscopic models and evaluate timetable feasibility. Capacity estimation is based on a new max-plus algebraic model for evaluating corridors, stations and networks. Further, we propose an alternative optimization model based on a periodic event scheduling network to simultaneously maximize timetable stability and robustness. Finally, we calibrate rolling stock characteristic parameters to provide reliable input to the overall planning framework.

In essence, this thesis demonstrates that optimization, simulation and data analysis can be successfully applied to improving railway traffic planning and account for better infrastructure capacity use and increased level of service for passengers and freight operators.

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Advanced Nonlinear Control Concepts for Freeway Traffic Networks

Maria Kontorinaki

Abstract

Despite the continuous advances in the field of Nonlinear Systems and Control, the design and deployment of efficient control algorithms, originated from this field and which can be applied for Traffic Control, remains a significant objective. This thesis is one of the first attempts towards this direction.

First, it introduces a general class of first-order models that can be used to represent a wide variety of traffic networks, such as freeways, interconnection of freeways and urban networks. The developed models correspond to large-scale discrete space-time dynamical systems that are highly nonlinear and uncertain. After testing in calibration and validation using real traffic data, it has been shown that these models are accurate enough in reproducing correctly the desired traffic patterns and the capacity drop phenomenon at an active bottleneck.

Second, the developed models have been utilized in order to develop a rigorous methodology for traffic control that provides explicit feedback control laws for the robust global exponential stability of any selected uncongested equilibrium point of the above networks. The stabilization is achieved by means of Lyapunov Function criteria and Graph Theory tools and exploits several important properties of the network models. The achieved stabilization is robust with respect to (i) the overall uncertain nature of network models when congestion phenomena are present, and (ii) the uncertainty stemming from the fundamental diagram selection. Potential applications of the developed control methodology include urban and peri-urban signal control, perimeter control, ramp metering and mainline metering.

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Cristina Olaverri-Monreal, Editor

Center for Robotics at MINES ParisTech

EDITOR'S NOTE

Please send your proposal on profiling research activities of your or other ITS research groups & labs in the ITS Research Lab Column to Cristina Olaverri-Monreal via olaverri@technikum-wien.at

Mission

PSL Research University is a young institution, created in 2010 through the leadership of Schools and research institutions themselves steeped in rich, centuries-old history. PSL's institutions, international in scope since their very beginnings, wanted to unite to more fully harness the academic adventure of the 21st century. The major research focus is to solve the world's problems. PSL ranks first among French universities and per THE (Times Higher Education), PSL's reputation rank is 41 in 2018.

MINES ParisTech is now one School of PSL; it was created in 1783, when the exploitation of mines was a high-technology industry. Quite naturally, the skills of the School followed the development of industry and MINES ParisTech, nowadays, studies, develops and teaches all the useful techniques for engineers, including economic and social sciences. Thanks to its multidisciplinary teaching, the School trains non-specialized engineers, able to resolve a really complex problem, or to carry out an industrial project, and treat all the highly technical aspects, as well scientific, sociological, economic as ethical. The background of the School, connected to the industry of mines, concentrating all the scientific knowledge, opens all the fields of research today: transport, energy, mechanics, robotics... Ever since 1783, the School has always been able to keep ahead of a changing world by taking part and launching projects with future potential.

The Center for Robotics has been created in 1989 by Prof. Claude Laurgeau within MINES ParisTech. In consistency with the mission of MINES ParisTech, its mission was to study robotics systems and to apply robotics techniques for the industry and to train engineers and PhD students (until recently in France, it was better considered to have a MINES ParisTech engineering degree than a PhD). The Center for Robotics has developed a broad expertise, relying on 15 professors and

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QUICK FACTS

Center for Robotics

Affiliation: MINES ParisTech—PSL Research University

Website: http://caor-mines-paristech.fr/en/home/

Established: 1989

Research Focus: Applied Robotics, Autonomous driving, Cooperative systems, virtual reality, mobile mapping, logistics, control, AI & perception

Director: Prof. Arnaud de La Fortelle

Arnaud de La Fortelle is professor at MINES ParisTech. He has developed expertize in Intelligent Transportation Systems, particularly around cooperative and autonomous driving. He has engineer degrees from the French École Polytechnique and École des Ponts et Chaussées (2 top French institutions) and a Ph.D. in Applied Mathematics.

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8 permanent support staff, allowing to consider robotics systems from several points of view, and mainly applied to the automotive industry. The scientific themes are:

- Control and Planning
- Virtual reality and interactions
- Logistics
- 3D modeling of the environment (mobile mapping)
- Mobile robotics and software tools
- Perception & Machine learning

The Center for Robotics is also responsible for 2 post-master formations: One in Production systems and logistics, and Artificial Intelligence and gesture for the industry.

FIG 1 MINES ParisTech is located in the Latin Quarter, next to many PSL Schools and research institutes.

History

Since its creation in 1989, the Center for Robotics has consistently been focused onto 3 key objectives:

- Innovate in new transport concepts
- Experiment and evaluate these new concepts
- Technology transfer

From the 90s, the Center for Robotics has partnered with Inria to develop the concept of automated road (LaRA—La Route Automatisée—in French), going beyond Advanced Driver Assistance Systems toward fully autonomous vehicles. The cybercars (picture below) were designed at Inria, produced by an industrial partner and sold around the globe in the 2000s. This lead to several breakthrough in this domain and Inria with the Center for Robotics were involved in several French and European projects related to this topic (Cybercars, CityMobil, REACT...).

In the 2005 Inria and MINES ParisTech created formally the consortium LaRA. Cooperative autonomous driving was developed through communication systems. Autonomous driving became an international activity when industrial sponsors Peugeot, Valeo and Safran supported the creation of the International Research Chair *Drive for All* in 2014 by a grant of 4 M€, with partners UC Berkeley, Shanghai Jiao Tong University and EPFL.

This strong partnership with the automotive industry was not exclusive. The Center for Robotics also developed smaller robots: in 2010 and 2011 the team Corebots lead by the Center for Robotics won twice the first place of the French robotics challenge CAROTTE. This success stimulated a technology transfer and part of the team went to a spinoff, Nexter Robotics. Several other companies also got commercial software licenses.

The same way of combining excellence in fundamental research and application explains that the Center for Robotics is recognized by the industry: dozens of patents are shared with industrial partners and there is about 1 start-up creation per year (e.g. YoGoKo winner of the 2014 i-LAB Contest). This explains also why industrial partners have funded 2 other Chairs: one on Robotics and Virtual Reality, and the other on Urban Logistics.

Finally, the excellence in fundamental research is emphasized by the prizes won by the researchers: e.g. recently Prof. Bonnabel was recipient of the SEE-IEEE Price Alain Glavieux in 2015, associate researcher Michel Fliess received the Ampere Prize of the French Academy of Sciences in 2015 and some best paper awards. And

FIG 2 MINES ParisTech partnered with Inria to advance road automation within the LaRA consortium, starting in the 90 s. Left, a Cybercar, right cooperative vehicles.

FIG 3 The Corebots small robot won several prizes and lead to technology transfer.

RELATED INFORMATION

- Website: http://caor-mines-paristech.fr/en/home/
- IEEE ITSS: http://sites.ieee.org/itss/
- ITS Podcast: http://itsp.cicei.com/
- Related Conferences: http://iv2019.org/

by the responsibilities given to some professors: Prof. de La Fortelle was president of the scientific evaluation committee of the French Research Agency for the domain of Sustainable Transport and Cities.

Future Directions

The Center for Robotics aims at keeping its successful model of combining fundamental research and to apply it with industrial partners. Our goal is to further push this accomplishment beyond the national level: the example of the International Chair Drive for All is inspiring and the Center for Robotics is more and more implied at the international level. Through visits of professors (with UC Berkeley), or exchange of students (with MIT, SJTU, KIT or Berkeley). Through the organization of international Summer Schools (Cooperative Interactive Vehicles with KIT, Human Factors Aspects in Cooperative System Design with TUM). And through organization of major conferences as IEEE Intelligent Vehicles Symposium to be held in Paris in June 2019.

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PHD & MPHIL THESES' ABSTRACTS *(continued from page 49)*

Finally, by exploiting tools from Adaptive Control, this thesis proposes a general methodology for the development of generic adaptive control schemes, which have limited requirements with respect to the knowledge of system parameters. The application of the proposed control schemes guarantee the robust global exponential attractivity of the desired and unknown uncongested equilibrium point for the closed-loop freeway systems. The proposed adaptive control schemes can be directly applied both as local and as coordinated real-time control strategies, as indicated by the results of the thesis

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Vision-Based Navigation System for Unmanned Aerial Vehicles

Abdulla Al-Kaff

Abstract

The main objective of this dissertation is to provide Unmanned Aerial Vehicles with a robust navigation system; to allow the UAVs to perform real-time complex tasks autonomously. The proposed algorithms deal with solving the navigation problem for outdoors and indoors, mainly based on visual information. In addition, this dissertation presents the advantages of using the visual sensors as the main source of data, or complementing other sensors in providing useful information; to improve the accuracy and the robustness of the sensing purposes.

The covers several research topics based on computer vision techniques: (I) Pose Estimation, to provide a solution for estimating the UAV 6D pose. This algorithm is based on the combination of SIFT-FREAK; which maintains the performance of the feature points matching and decreases the computational time. Thereafter, the pose estimation problem is solved based on the decomposition of the world-to-frame and frame-to-frame homographies. (II) Obstacle Detection and Collision Avoidance, in which, the UAV is able to sense and detect the frontal obstacles that are situated in its path. The detection algorithm mimics the human behaviors for detecting the approaching obstacles; by analyzing the size changes of the detected feature points, combined with the expansion ratios of the convex hull constructed around the detected feature points. Then, by comparing the area ratio of the obstacle and the position of the UAV, the method decides if the detected obstacle may cause a collision. Finally, the algorithm extracts the collision-free zones around the obstacle and the UAV performs the avoidance maneuver. (III) Navigation Guidance, which provides a strategy to follow the path segments and in an efficient way and perform the flight maneuver smoothly. (IV) Visual Servoing, to offer different control solutions (Fuzzy Logic Control (FLC) and PID), based on the obtained visual information; to achieve the flight stability as well as to perform the correct maneuver; to avoid the possible collisions and track the waypoints.

All the proposed algorithms have been verified with real flights in both indoors and outdoors. The obtained results have been validated against other systems; such as VICON system, DGPS in the case of pose estimation.

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