JÁRMŰIPARI KUTATÓKÖZPONT
RESEARCH CENTER OF VEHICLE INDUSTRY

# WORKSHOP ON DESIGN, SIMULATION, OPTIMIZATION AND CONTROL OF GREEN VEHICLES AND TRANSPORTATION

21-23 MAY, 2014
Győr, Hungary

SZÉCHENYI ISTVÁN UNIVERSITY
SZE - GYŐR

JÁRMŰIPARI KUTATÓ KÖZPONT
RESEARCH CENTER OF VEHICLE INDUSTRY

inno mobilitas

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# WELCOME

Dear DSOC Participant,

we welcome you on the 1st DSOC workshop at the Széchenyi István University in Győr!

This workshop is a scientific event of the projects running at Research Center for Vehicle Industry of the Széchenyi István University, Győr, Hungary under the grants TÁMOP-4.2.2.A-11/1/KONV-2012-0012 and TÁMOP-4.2.2.C-11/1/KONV-2012-0012. Under these projects we perform research for solving some challenges of modern societies about green vehicles and smart transportation. More specifically, the conference themes are focused on construction and development of electric motors for vehicles, urban traffic flow and its environmental effects with pollutant formations.

The engineering goals cannot be achieved without using the methods of mathematical modelling, computer simulation, optimization and control, which altogether have become recently one of the key enabling technology of the industry. Within the themes scientific background and application of this technology concerning the electric vehicles and urban traffic should be presented. To support this aim and serve young and new researchers of the fields, some tutorials are organized as part of the workshop. Moreover lectures from industry make the workshop vital.

We wish you a pleasant stay and we are looking forward to an exciting workshop!

Kind regards,

DSOC Workshop Organizers

| | | |
|---|---|---|
| József Bokor | László Palkovics | Zoltán Horváth |
| Péter Gáspár | Zoltán Varga | Balázs Horváth |

# Keynote speakers

## Bittner, Florian (Audi AG, Ingolstadt)

- Title: Design, Simulation and Optimization of Electric Machines for Green Vehicles
- Date: 22 May, 2014 10:15 – 10:55

## Elizondo, David (De Montfort University, Leicester)

- Title: Range Extended Engine Management System for Electric Vehicles: A Computational Intelligence Approach
- Date: 23 May, 2014 09:40 – 10:20

## Göttlich, Simone (University of Mannheim, mannheim)

- Title: Traffic light control on road networks
- Date: 23 May, 2014 09:00 – 09:40

## Horváth, Zoltán (Széchenyi István University, Győr)

- Title: Applications and development of the Modeling-Simulation-Optimization technology to green vehicles and transportation
- Date: 22 May, 2014 09:10 – 09:35

## Palkovics, László (Knorr Bremse Systems for Commercial Vehicles and Széchenyi István University, Győr)

- Title: Autonomous Drive of Commercial Vehicles as Contributor to GHG Emission Reduction - Platform Systems and their Control
- Date: 22 May, 2014 09:35 – 10:15

## Passow, Benjamin (De Montfort University, Leicester)

- Title: Integrated Traffic Management and Air Quality Control
- Date: 22 May, 2014 14:00 – 14:40

# Tutorial

## Ketcheson, David (King Abdullah University of Science and Technology, Thuwal)

- Title: An introduction to hyperbolic conservation laws with PyClaw
- Date: 21 May, 2014 09:00 – 17:00

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# PROGRAM OVERVIEW

| | Room: ÚT 220 |
|---|---|
| | **21 May, 2014** |
| 08:45-15:00 | Registration |
| 09:00-12:00 | Tutorial 1<br>David Ketcheson |
| 12:00-13:00 | Lunch break |
| 13:00-17:00 | Tutorial 2<br>David Ketcheson |

| | Room: F | Room: G | Room: VIP |
|---|---|---|---|
| | **22 May, 2014** | | |
| 08:30-15:00 | Registration | | |
| 09:00-09:10 | Péter Földesi, József Bokor | | |
| 09:10-09:35 | Zoltán Horváth | | |
| 09:35-10:15 | László Palkovics | | |
| 10:15-10:55 | Florian Bittner | | |
| 10:55 -11:10 | Break | | |
| | Design (F. Bittner) | Modeling and Control (P. Gáspár) | Positivity (Z. Horváth) |
| 11:10-11:30 | Márton Kuslits | Zoltán Szabó | David Ketcheson |
| 11:30-11:50 | Miklós Kuczmann | József Tar | Inmaculada Higueras |
| 11:50-12:10 | János D. Pintér | Krisztán Kósi | Helmut Podhaisky |
| 12:10-12:30 | István Szénásy | István Pintér | Mihály Markót |
| 12:30-14:00 | Lunch break | | |
| | Smart Transportation (S. Göttlich) | | |
| 14:00-14:40 | Benjamin Passow | | |
| 14:40-14:50 | Break | | |
| | Smart Transportation (B. Passow) | Modeling and Control (Z. Szabó) | |
| 14:50-15:10 | Tamás Tettamanti | Tímea Fülep | |
| 15:10-15:30 | Bence Liszkai | Péter Bauer | |
| 15:30-15:50 | Gábor Takács | Balázs Németh | |
| 15:50-16:10 | Balázs Horváth | Tihamér Kocsis A. | |
| 16:30-16:50 | Break | | |
| | Smart Transportation (D. Elizondo) | Simulation (L. Molnár) | Positivity (D. Ketcheson) |
| 16:50-17:10 | Imre Felde | Csaba Gáspár | Lajos Lóczi |
| 17:10-17:30 | Csaba Csiszár | Abdelhakim Lotfi | Yunfei Song |
| 17:30-17:50 | Éva Pestiné Rácz | László Környei | Zoltán Horváth |
| 17:50-18:10 | Zsuzsanna Bede | Christian Kiss-Tóth | |
| | | | |
| 19:00-22:00 | Conference Dinner | | |

| | Room: F |
|---|---|
| | **23 May, 2014** |
| 08:45-12:00 | Registration |
| 09:00-09:40 | Simone Göttlich |
| 09:40-10:20 | David Elizondo |
| 10:20-10:30 | Break |
| | Design (D. Fodor) |
| 10:30-10:50 | Imre Czinege |
| 10:50-11:10 | Zoltán Varga |
| 11:10-11:30 | János Kokavecz |
| 11:30-11:50 | Bence Kocsis |
| 11:50-13:00 | Lunch break |
| | Design (Z. Varga) |
| 13:00-13:20 | Ádám Bakos |
| 13:20-13:40 | István Szalay |
| 13:40-14:00 | Krisztián Enisz |
| 14:00-14:10 | Closing |

# PROGRAM 21 MAY, 2014

## TUTORIAL: NUMERICAL SOLUTION OF HYPERBOLIC CONSERVATION LAWS: A PRACTICAL INTRODUCTION

### LECTURER: DAVID KETCHESON (KING ABDULLAH UNIVERSITY OF SCIENCE AND TECHNOLOGY)

- Date: 21 May, 2014 9:00 – 17:00
- Place: Széchenyi István University, Győr (Room: UT. 220)

This course will cover the basic theory and numerical solution of hyperbolic conservation laws, including models of traffic flow and fluid dynamics as examples. Concepts will be introduced in the context of one-dimensional scalar problems, and then applied to more complex problems including multidimensional fluid dynamics. The ideas will be illustrated and explored using the PyClaw software. Students will be taught how to use PyClaw to solve problems of their own interest.

Students should have some scientific programming experience and a basic understanding of differential equations. The course will use the Python programming language, but prior experience with Python is not necessary. No software installation is necessary; everything required for the course will be provided via SageMathCloud. Participants who wish to preinstall the PyClaw software on their own computer may follow theinstructions in the Clawpack documentation.

1. Setup
   - SageMathCloud
   - IPython notebooks
   - Python tutorial
2. Scalar conservation laws
   - Advection and characteristics
     - Upwind method and the CFL condition
   - The LWR traffic model
     - Shock formation
     - Vanishing viscosity, weak solutions, and the entropy condition
     - The Riemann problem and Rankine-Hugoniot conditions
3. Godunov-type methods
   - Finite volume discretization
   - Riemann solvers
   - Slope limiters
4. Systems of hyperbolic PDEs
   - Linear systems
   - Nonlinear systems: the Euler equations
   - Approximate (linearized) Riemann solvers and Roe's solver
   - Entropy fix
5. Solving problems with PyClaw
   - Examples
   - Setting up problems in 1 and 2 dimensions
   - Running in parallel
   - Solver options (Classic and SharpClaw)
   - Extensions to more general problems
     - Time for participants to experiment or implement their own problems

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# PROGRAM 22 MAY, 2014

| | Room: F | Room: G | Room: VIP |
|---|---|---|---|
| 09:00-09:10 | Péter Földesi, József Bokor | | |
| 09:10-09:35 | Zoltán Horváth<br>*Applications and development of the Modeling-Simulation-Optimization technology to green vehicles and transportation* | | |
| 09:35-10:15 | László Palkovics<br>*Autonomous Drive of Commercial Vehicles as Contributor to GHG Emission Reduction - Platform Systems and their Control* | | |
| 10:15-10:55 | Florian Bittner<br>*Design, Simulation and Optimization of Electric Machines for Green Vehicles* | | |
| 10:55 -11:10 | Break | | |
| | Design (F. Bittner) | Modeling and Control (P. Gaspar) | Positivity (Z. Horváth) |
| 11:10-11:30 | Márton Kuslits<br>*Driving cycle based cost function for energetic optimization of PMS motors applied in electric vehicles* | Zoltán Szabó<br>*Guaranteed performance with analysis oriented KYP lemma* | David Ketcheson<br>*High order strong stability preserving general linear methods* |
| 11:30-11:50 | Miklós Kuczmann<br>*Numerical electromagnetic field analysis in electrical machine simulation* | József Tar<br>*Resolution of Kinematic Constraints via Local Optimization in an Adaptive Dyanamic Control of an Electric Cart* | Inmaculada Higueras<br>*Numerical positivity: from theory to practice* |
| 11:50-12:10 | János D. Pintér<br>*How difficult is nonlinear optimization?* | Krisztán Kósi<br>*A novel type model reference adaptive controller for the dynamic control of a WMR* | Helmut Podhaisky<br>*On positive explicit peer methods of high order* |
| 12:10-12:30 | István Szénásy<br>*Optimum control strategy for vehicle PMSM in field-wakening operation* | István Pintér<br>*Design and realization of FFNN-based neurocontroller for HEV* | Mihály Markót<br>*Complete global optimization methods for finding positively invariant sets of ordinary differential equations* |
| 12:30-14:00 | Lunch break | | |

# PROGRAM 22 MAY, 2014

| | Room: F | Room: G | Room VIP |
|---|---|---|---|
| | Smart Transportation | | |
| 14:00-14:40 | Benjamin Passow<br>*Integrated Traffic Management and Air Quality Control* | | |
| 14:40-14:50 | Break | | |
| | Smart Transportation (B. Passow) | Modeling and Control (Z. Szabó) | |
| 14:50-15:10 | Tamás Tettamanti<br>*Data fusion concept for urban traffic estimation based on heterogeneous data* | Tímea Fülep<br>*Control design for in-wheel vehicles* | |
| 15:10-15:30 | Bence Liszkai<br>*Computational simulation of air pollution dispersion induced by urban traffic* | Péter Bauer<br>*Optimality and performance of reference tracking solutions* | |
| 15:30-15:50 | Gábor Takács<br>*Predicting flight arrival times with a multistage model* | Balázs Németh<br>*Polynomial analysis of steering and braking interventions based on invariant sets* | |
| 15:50-16:10 | Balázs Horváth<br>*Elements of Smart Transport* | Tihamér A. Kocsis<br>*On a control method for a vehicle dyamics problem* | |
| 16:30-16:50 | Break | | |
| | Smart Transportation (D. Elizondo) | Simulation (L. Molnár) | Positivity (D. Ketcheson) |
| 16:50-17:10 | Imre Felde<br>*Using wireless data to characterize urban traffic* | Csaba Gáspár<br>*A Regularized Method of Fundamental Solutions for Heat Transfer Problems* | Lajos Lóczi<br>*On the stability regions of implicit linear multistep methods* |
| 17:10-17:30 | Csaba Csiszár<br>*Personalized information services affecting mobility decisions and processes* | Abdelhakim Lotfi<br>*Numerical investigation of heat transfer in air cooled Permanent Magnet electrical machines* | Yunfei Song<br>*Steplength thresholds for invariance preserving of discretization methods of dynamical systems* |
| 17:30-17:50 | Éva Pestiné Rácz<br>*Measuring small scale differences of traffic caused air pollution in a street canyon* | László Környei<br>*Simulation of Heat Dissipation in a PMS Motor with OpenFOAM* | Zoltán Horváth<br>*Positively invariant sets for differential equations and their discretizations* |
| 17:50-18:10 | Zsuzsanna Bede<br>*Theory of variable network model and application of RLS in Győr* | Christian Kiss-Tóth<br>*Optimizing airplane routes with dynamic programming* | |

19:00 Conference Dinner

# PROGRAM 23 MAY, 2014

| | Room: F |
|---|---|
| 09:00-09:40 | Simone Göttlich<br>*Traffic Light Control on Road Networks* |
| 09:40-10:20 | David Elizondo<br>*Range Extended Engine Management System for Electric Vehicles: A Computational Intelligence Approach* |
| 10:20-10:30 | Break |
| | Design (D. Fodor) |
| 10:30-10:50 | Imre Czinege<br>*Energy efficiency of electric vehicles* |
| 10:50-11:10 | Zoltán Varga<br>*Research and development of vehicles' driving systems for sustainable city traffic* |
| 11:10-11:30 | János Kokavecz<br>*Highly resonant wireless power transfer* |
| 11:30-11:50 | Bence Kocsis<br>*Research of hybrid vehicle design* |
| 11:50-13:00 | Lunch break |
| | Design (Z. Varga) |
| 13:00-13:20 | Ádám Bakos<br>*Modelling and control of permanent magnet synchronous machines for electric vehicles* |
| 13:20-13:40 | István Szalay<br>*Including the shaft position information in the model of an PMSM motor for sensorless control application* |
| 13:40-14:00 | Krisztián Enisz<br>*Extended Kalman filter based tyre-road friction coefficient estimation in HIL environment* |
| 14:00-14:10 | Closing |

# ABSTRACTS

## Modelling and control of permanent magnet synchronous machines for electric vehicles

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In electric vehicles usually permanent magnet synchronous machines are used as electric drives. To achieve the highest possible efficiency using these machines, a control-oriented mathematical model of the motor and an appropriate control method must be used. The presentation describes these models and control algorithms that are used in our research projects.

## Optimality and performance of reference tracking solutions

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Reference tracking solutions are necessary in most of the control applications. In electrical vehicles, tracking control can be used for several tasks such as control of electric motor RPM, vehicle velocity or steering angle. It is important to solve these tasks with minimum energy consumption and maximum accuracy. In industrial implementation the computational cost of the algorithms should be also considered. Linear quadratic control methods are suitable to consider both energy consumption and tracking accuracy through the applied quadratic functional.

This presentation will briefly overview some possible linear quadratic (LQ) functional based reference tracking solutions and compare them regarding optimality and computational requirements. The performance of each method will be compared through a simple example.

Tracking of a constant nonzero reference usually requires a nonzero control input and this results in infinite LQ functional (regarding infinite time horizon) and so no optimal solution exists. This problem can be overcome by considering a controlled system centralized around a given constant or time-varying reference point.

The solutions applied to the centralized system are simple LQ optimal regulation which drives its state into zero, model predictive control, preview control and a solution developed by the author in previous works ([1] for example).

The possible optimality (finite functional value on infinite horizon and existence of a solution), the computational requirements and performance will be compared and demonstrated listing the advantages and drawbacks of each solution.

[1] Peter Bauer and József Bokor: Infinite horizon LQ optimal output tracking from development to real flight tests, Proceedings of the 12th IEEE International Symposium on Computational Intelligence and Informatics (CINTI 2011) pp. 277-282, November 21-22, Budapest, Hungary, 2011.

# Theory of variable network model and application of RLS in Győr

Zsuzsanna Bede, Tamás Péter
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The goal of this paper is to explore and analyse the possible application of the state-dependent control by changing the structure of the road traffic system. The resulting Reversible Lane System (RLS) is one of the used solution techniques to optimise the traffic control. The model of RLS was created based on a simple part of a road network, which is segmented into elements. In case of a lane direction changing the contacts between each element remain the same, while the functions of the network elements are swapped. Therefore the structure of the network model has to be dynamically changed, which requires a new kind of optimal control. On the other hand the traffic density is continuously changing, which increases the complexity of the model. The created model was used to simulate a real traffic network by applying the real, existing setting parameters of the traffic lights. The availability of the RLS was examined in a sample network depending on the traffic density, using a new principle, which responses to the dynamic change of the structure of the network graph.

# Design, simulation and optimization of electric machines for Green Vehicles

Florian Bittner
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As current sales reports are showing, the market for green vehicles is growing steadily. In order to persist in the global competition it is essential for car manufacturers to develop hybrid and electrical cars that perfectly match their customers' needs. Aspects like the daily driving range require different degrees of electrification and car concepts, which subsequently influence the choice of the most suitable type of electric machine. In hybrid cars, permanent magnet synchronous machines (PMSM) are used almost exclusively.

For the design optimization of PMSM a novel combination of a multi-objective particle swarm optimization algorithm and a Kriging metamodel was developed. This fast converging algorithm is used to solve the mostly conflicting objective functions which are based on computational expensive numerical field simulations. As an example the design optimization of a 10 poles PMSM with 11 parameters and 3 objectives is presented.

# Energy efficiency of electronic vehicles

Imre Czinege
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Development trends of electronic vehicles. Overall efficiency and analysis of units. Detailed discussion of grid-to-wheel efficiency, battery characteristics, performance of electric cars, road load components, effect of mass reduction on energy use.

# Personalized information services affecting mobility decisions and processes

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Due to the spread of mobile communication devices a variety of the information services appears that support the mobility decisions of travelers and then their guidance. Since quality of mobility chains depends on the features of its elements, therefore information provision in all phases is required. In order to enhance perceived quality personalization methods for traveller assistant applications have been devised. During the research several mobility applications have been compared as well as the habits and expectations of the travelers have been revealed. For analysis and evaluation of the multimodal journey planners a framework of aspects has been developed, so that they can be compared in a quantitative way and ranked by functional, operational and visualization features. As it turned out all of the forward-looking features are still not combined into one application and the personalization is limited. For demonstration of the operation several partial applications have been developed. Not only the real-time but the estimated arrival times and the time elements regarding the preceding vehicle movements should be considered, therefore an innovative methodology based on the historical data has been elaborated for the estimation of time elements. Finally the directions of the further research have been determined, which are the followings: multimodality, real-time and estimated data and location-based services.
Keywords: integrated information system, multimodal transportation, mobility management, personalization, time estimation

# Extended Kalman filter based friction coefficient estimation in HIL environment

Krisztian Enisz, Dr. Denes Fodor, Istvan Szalay, Gabor Kohlrusz, Zoltan Marton, Klaudia Nagy
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Nowadays – in order to satisfy the increasing need for security and comfort – the active safety systems and the related researches are among the most dynamically evolving areas.

At the same time not only the vehicles but the road surfaces are evolving. In the developed countries lowering the accident rates are among the top priorities. Due to the strict regulations, the road constructors are investigating more and more intensively the ways of producing road surfaces with better traction meanwhile trying to achieve a surface that has better resistance against wear.

It is very important to investigate the different road surfaces in respect of friction coefficient to reach better performance in operating the vehicle safety systems such as ABS (anti-lock braking system) and ESP (electronic stability program).

The aim of the research was to develop a new algorithm able to estimate the instantaneous and maximum values of tire-road friction coefficient to improve the active safety systems in today cars. The algorithm applies the discrete-time extended Kalman filter for state estimation. Based on two-wheel longitudinal vehicle dynamics a discrete-time nonlinear state-space model has been implemented. The model has been extended to include the scale factor parameter of the Magic Formula for longitudinal tire force introduced by Pacejka.

A new real-time HIL (Hardware-In-the-Loop) simulation environment was created for verifying the Kalman filter based algorithm and the results were in concordance with the expectations.
Keywords: Friction coefficient, vehicle dynamics, Kalman filter, state estimation, HIL

## Using wireless data to characterize urban traffic

László Nádai, Imre Felde
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Large-scale urban sensing data such as mobile phone traces are emerging as an important data source for urban traffic modeling. The determination of OD matrices, POIs and efficiency of public transport can be characterized by using mobile phone records. In this paper, we present techniques to apply formerly collected mobile phone data for determination of home, workplace, etc and type of traveling used by the public in Győr (Hungary). The mobile-phone-based mobility measures are compared to mobility measures obtained by loop detectors and traffic camera records. The empirical results can help us understand the intra-urban variation of mobility and the non-vehicular component of overall mobility.

## Control design for in-wheel vehicles

Tímea Fülep
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The presentation proposes the design of an integrated vehicle control system for in-wheel electric vehicle, which is able to track road geometry with a predefined reference velocity. In the design the lateral and longitudinal dynamics are combined using the in-wheel motors and the steering system. The design methodology of the hierarchical control is proposed. The required control signals are calculated by applying high-level controllers, which are designed using a robust control method. For the control design the model is augmented with weighting functions specified by the performance demands. The actuators generating the necessary control signals in order to achieve the requirements for which low-level tracking controllers are designed.

# A regularized method of fundamental solutions for heat transfer problems

Csaba Gáspár
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The Method of Fundamental Solutions (MFS) is a popular meshless method for solving potential problems e.g. in heat transfer, seepage problems etc. In its original form, the MFS produces an approximate solution of the problem in a form of a linear combination of the fundamental solution shifted to some external points (source points). The a priori unknown coefficients can be obtained by enforcing the boundary conditions at some boundary collocation points. The method exhibits excellent accuracy; however, it leads to extremely ill-conditioned linear system of equations, especially when the source points are located far from the boundary. On the other hand, if they are too close to the boundary, numerical singularities are generated, which destroy the accuracy.

In this talk, some regularization techniques are presented, which avoid the problem of singularity. They produce much better conditioned linear systems, while the accuracy still remains acceptable. For treating Neumann boundaries, some more sophisticated desingularization tools are needed due to the stronger singularities that appear in the derivatives of the fundamental solution. Both monopole and dipole formulations are investigated; the first method can be considered a discrete version of an indirect boundary integral equation based on a single layer potential, while the second one is related with the double layer potentials. Finally, the approach is generalized to various types of interface problems as well, which appear in heat transfer problems in composite objects in a natural way. The basic idea is to locate extra sources and/or dipoles along the interfaces to satisfy the interface conditions. Numerical examples are also presented.

# Traffic light control on road networks

Simone Göttlich
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Traffic flow phenomena can be described by a continuous traffic flow network model incorporating constraints for optimal traffic light switchings in time. The focus is on the discussion of the extended traffic model and the derivation of a suitable optimization framework to determine the optimal switching points.

In fact, the model can be related to mixed-integer programming models that allow for Branch and Bound based optimization procedures Instead of descent-type methods. To ensure feasibility and to reduce the computational effort of large-scale instances, there is evidently need for suitable heuristics.

# Numerical positivity: from theory to practice

Inmaculada Higueras
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Spacial discretization of some partial differential problems (PDEs) give rise to ordinary differential equations (ODEs). Sometimes, the solutions to these PDEs have qualitative properties, e.g., monotonicity, positivity, etc., which are relevant in the context of the problem. In these cases, it is convenient to preserve numerically these properties. In this talk we will focus on numerical positivity in the time stepping process.

During the last decade, a great progress has been done in theoretical aspects of numerical positivity and nowadays it is still an active research line. However, from the point of view of applications, it is important to bring theory to practice.

In this talk we will review the most relevant ideas in numerical positivity and we will discuss how these results can be used in applications. In particular, we will show how robust schemes can be constructed and their performance on some nontrivial problems.

# Elements of Smart Transport

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The presentation gives a short overview on the project "Smarter Transport" which aim is to define the elements and the needed cooperation level between these elements to have a smart transport system. Delve into the depths of the topic it will be shown the elements of a smart transport system and the existing or missing connection between them. It will be discussed how is it possible to have instead of a series of "island" applications a cooperative network of intelligent solutions which can lead through smart transport to smart city. Furthermore there will be some project shown as initiative to have ones a sustainable smart transport system.

The research resulted these achievements is supported by the „TÁMOP-4.2.2.C-11/1/KONV-2012-0012: "Smarter Transport" - IT for co-operative transport system" project - The Project is supported by the Hungarian Government and co-financed by the European Social Fund

# Applications and development of the Modeling-Simulation-Optimization technology to green vehicles and transportation

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Beyond doubt mathematical modeling, simulation and optimization (MSO) methods for problems of industry and society has been forming recently one of the key technologies in research, innovation and daily routine design as well. In this lecture we provide some notes of applications of the MSO technology to electric motors and dispersion simulation and optimization of urban traffic emitted pollutions under real geometry constraints. Of course, we shall deal with validation issues of the models and simulations and discuss possibilities of optimization as well.

Development of the mathematical methods behind the MSO tools is a must to have modern technology; in this lecture we show illustrative examples for how the theory and methods of numerical analysis and optimization contribute in control and its application to vehicle dynamics as well.

## Positively invariant sets for differential equations and their discretizations

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For efficient and physically reliable numerical computations for time dependent differential equations modeling, e.g. heat and material transport it is very important to find positively invariant subsets of the state space and determine time step sizes of the numerical method that guarantee this. Equally important is finding functionals of the solution that decrease in time and preserving this diminishing property under the time discretization. This field is highly related to finding Liapunov functions for differential equations and their disretizations.

In this talk we present a general framework for analysing numerical methods of a broad family to determine time step sizes that guarantee preservation of positively invariant convex sets and the discrete Liapunov property for convex Liapunov functions. We shall set up some novel approaches as well to find positively invariant sets and the suitable time step sizes via optimization technics.

## High order strong stability preserving general linear methods

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Explicit strong stability preserving methods are widely used in the solution of hyperbolic conservation laws. They allow certain spatial discretizations to be integrated to high accuracy in time without introducing spurious oscillations or unphysical negative values. They are commonly paired with WENO or discontinuous Galerkin spatial discretizations of high order. But SSP Runge-Kutta methods have order at most four, and SSP multistep methods have small step size restrictions. Many researchers have now begun investigating the use of multiple steps and multiple stages in order to find higher order methods with large admissible step sizes. I will give an overview of results in this area, including my own work on the simple but efficient class of multistep Runge-Kutta methods. I will also discuss the relatively neglected issue of step size adaptation for these methods, and how it can be achieved without sacrificing the strict monotonicity property.

## Optimizing airplane routes with dynamic programming

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In this talk we present an approach to optimize airplane routes by minimizing the total cost of the flights. Making flights more efficient in real time, avoiding costly delays by taking control on weather conditions, such as wind, turbulences or dangerous zones and gate conflicts during the arrivals is an important issue of air transport. We developed a method using dynamic programming and local search techniques to solve this problem. The efficiency of our process will be illustrated by various numerical examples and visualization of flight paths.

# Research of hybrid vehicle design

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Current presentation summarizes the majority of the project "Research of hybrid and electronic vehicle design". Aim of the project was to find a sufficiently up-to-date hybrid drive train and to accomplish an intelligent control between its internal combustion engine and electric machine. For this reason a number of models had to be designed, additionally an appropriate environment was required and established. Following a combined evaluation of every model, under both, objective and subjective aspects, the most suitable was selected to conduct further detailed evaluation. The detailed analysis was achieved in two essentially different ways. Firstly, a parameter sensitivity analysis was conducted, in order to observe certain trends in the behavior of the vehicle model. Secondly, the implementation of the vehicle model into the controller development environment had to be executed. For what, the controllers had to be designed first, and then introduced to the optimal control criteria of energy management (in form of mathematical equations), to achieve the optimal control as accurately as possible. With all the simulations done, a thorough evaluation of the parameter sensitivity analysis and a comparison of the controllers followed. The project will be completed after the upcoming last part 'Research on predictive algorithms on energy-management' is executed successfully.

# On a control method for a vehicle dyamics problem

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In this talk we present an approach to find the controlled invariant sets of a nonlinear dynamical system. Our method explores the state space and determines the set of those initial values where the system can be stabilized with a bounded control function. A continuous closed-loop feedback rule can also be obtained from this procedure. We illustrate the numerical results of our method on a problem describing the behavior of vehicle actuators.

# Highly resonant wireless power transfer

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The idea of transmission of electricity without cables has been around for over a century, with Nikola Tesla's pioneering experiments. Wireless Power Transfer (WPT), due to automatic and contactless power transmission, may be especially advantageous for hybrid and electric vehicles. The recharge process of the propulsion battery may occur more often using WPT chargers. Hence, the capacity as well as the price of the installed propulsion battery system may be reduced and the decreased mass of the vehicle can further improve efficiency.

In present contribution, we shortly introduce the theory of highly resonant wireless power transfer. We show that the weak coupling between the transmitter and receiver devices, which is characteristic to WPT can be counterbalanced by an enhanced quality factor of both the receiver and transmitter resonators. Compared to transformers, the coupling is not only significantly weaker, but also it may vary as the relative movement of the receiver and transmitter. To establish clean power delivery to the receiver, a closed loop control of the delivered power should be implemented in order to eliminate the power fluctuations resulted by the varying coupling. Next, we review the possible communication channels which are essential for the controlled power delivery. We pay special attention to the recommendations of the Wireless Power Consortium. At last, we show the technical details and test results of a low power magnetically coupled WPT system.

# A novel type model reference adaptive controller for the dynamic control of a WMR

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In the model-based dynamic control of the Wheeled Mobile Robots (WMR) normally simlified models are used in which the motion of the mass center point of the device is directly tracked/controlled. The dynamic equations of motion are far more complicated if the tracked point is an arbitrarily selected point of the device, and the orientation of the robot is described by rotations around this point. The "Model Reference Adaptive Controller (MRAC)" has the great advantage that besides guaranteeing precise trajectory tracking it can generate the illusion for an external control loop that it deals with a device of simple dynamic behavior. The MRAC controllers traditionally are designed by the use of Lyapunov 2nd Method. In the presentation the application a far simpler method based on the application of Robust Fixed Point Transformations is used for the compensation of the consequences of the use of an imprecise model due to which the controlled point differs from the mass center point of the WMR. It is illustrated via simulations the novel design methodology successfully can solve this task.

# Simulation of heat dissipation in a PMS motor with OpenFOAM

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PMS Motors are used widely in hybrid and electric cars and vehicles. Some of the critical events of failure are caused by certain parts overheating. It is mandatory, that the cooling of these parts are properly designed. Design, however, also includes implementing new ways to solve the issue of heat dissipation. Computational simulation is a great tool to prepare design decisions this way. In this work, the heat dissipation from a PMS motor is simulated with the OpenFOAM toolset. This software also enables running on high performance hardware with modern parallelization methods, like MPI. The actual challenge lies in the multiphase system, as heat transfer is modelled in both solid and vaporous materials. Tight spaces require a very fine mesh to properly describe air flow, which makes simulation more complex.

The PMS motor has some rotating parts while in operation, naturally. In OpenFOAM there are two ways to handle moving, translating, i.e. rotating parts. The first one is to divide the simulated space into two parts, a moving and a stationary one. These two parts are connected by a non-conform "sliding" interface, where boundary values are interpolated each for time step. The second one defines a deforming zone between the moving and the stationary part. However, this deforming zone can induce faulty cells, if the deformation is too severe. This is resolved by a preferably automatic meshing of the deforming space.

In this work the concept of the sliding interface is implemented. In OpenFOAM, the base solver for heat transfer in mixed solid and liquid environment is used and extended with heat source and mesh rotational capabilities. Also, the parallel version of the code is implemented, and its performance is measured and evaluated. The first results are presented in the talk.

# Numerical electromagnetic field analysis in electrical machine simulation

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The Finite Element Method (FEM) is a powerful technique to approximate the solution of partial differential equations. Electrical engineering problems can be solved by the use of Maxwell's equations and appropriate potentials or field quantities, i.e. by partial differential equations. Unfortunately, the FEM solvers are usually very slow, the software is too expensive, and the most of the potential formulations are not included, and so on. This is the reason why a new code has been developed. The most important aim is to realize fast FEM routines, because the algorithms will be used to optimize the geometry of a new motor applied in electric cars. Optimization is usually a time consuming and hardware consuming task, i.e. it is big challenge to develop a new software.

The computer aided design is one of the most important parts of the electric engine development. Electric engine development is nowadays in the focus at the Széchenyi István University. Mainly permanent magnet synchronous motors are used in electric cars, and the aim of this project is to reduce the weight and the size of the engine, as well as the losses of the motor, but the torque should not decrease. This is an optimization task in the frame of electrodynamics.

In this project the C programming language has been used, and this paper presents the different parts of the new environment.

## Driving cycle based cost function for energetic optimization of PMS motors applied in electric vehicles

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There is an increasing demand to improve energy efficiency in vehicle drives. This is also demanding in case of battery electric vehicles (BEV) due to the limits of battery capacity. In order to manage this challenge, a possible approach is to design precisely tailored electric machines for certain vehicle drive applications (e.g. for small urban BEV cars, utility vehicles, etc.). Energetic optimization based on driving cycles can be a possible method for this "tailoring".

As first step, a single-objective cost function was developed for this purpose. This cost function calculates the weighted sum of losses for a set of discrete points in a driving cycle therefore an energetic optimization can be implemented by minimizing the cost function.

As an optimization example, a simple outer rotor PMSM design optimization was implemented on the basis of the cost function.

## Computational simulation of air pollution dispersion induced by urban traffic

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All over the world, in almost every city the problem of the air pollution caused by urban traffic comes up. The harmful gases emissed by vehicles affect the inhabitants and environment badly. If we are able to predict the development and distribution of these dangerous gases, we could intervent into the system of the traffic, and hinder the rising of the gases over a critical level.

Within the confines of this 'Smarter transport' project we work on a simulation and optimisation technique, which may help to solve these problems mentioined above.

Nitrogen oxid emission is calculated based on the simulation of the city's traffic. With using of these results and with the help of 3D CFD simulation, we can estimate the spread of harmful gases. On the basis of the traffic measurements and weather forecast the nitrogen oxid distribution can be predicted. Using of these data and with the help of an optimisation method the traffic control system could be corrected, reducing the chance of reaching the critical level of the harmful gases.

# On the stability regions of implicit linear multistep methods

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In the first part of the talk we exactly determine, for the first time, the stability angles in the definition of A(α)-stability for the classical $k$-step BDF methods and for the $k$-step second derivative multistep methods of Enright. It turns out that the stability angle for each member of the BDF family can be expressed in an unexpectedly simple way. In the case of the Enright methods, the corresponding expressions are much more complicated. In the second part of the talk we show that if we apply the accepted definition to determine the stability region of implicit linear multistep or implicit multiderivative multistep methods, we find in many cases that there are some isolated points of stability within their region of instability. These points cannot be detected by the well-known root locus method, and their existence renders many results about stability regions contradictory. We suggest a new definition for the stability region excluding such singular points.

# Numerical investigation of heat transfer in air cooled Permanent Magnet electrical machines

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This work describes a computational study of the heat transfer in Radial Flux Permanent Magnet (RFPM) electrical machines with an outer rotor configuration. The heat generation in electrical motors is a direct result of the conversion of electrical and mechanical losses to heat. This may cause, however, a temperature rise of the stator thus reducing the life-span of the insulation materials. The heat is also transmitted to the other generator parts, such as the rotor, the rolling bearings and the magnets. These are particularly sensitive to temperature and may lose all or part of their magnetization when exposed to too high temperature.

The study is based on a direct coupling between the heat-transfer and fluid flow analysis to better understand the thermal state of the machine. For this purpose a computer code based on finite element approach and finite volume approach was developed to allow the fast and accurate estimation of the thermal and turbulent phenomena in electrical machines. The accuracy of the developed thermal model depends on the knowledge of the heat losses in the different parts of the machine and their distribution. Special attention is given to evaluate different loss components by using analytical and magneto-dynamic two dimensional finite element models. As the main heat sources in electrical machines, the obtained losses are used in the thermal model to calculate the temperatures of different machine components.

The results obtained by the model are compared with experimental results from testing the prototype electric motor.

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# Interval global optimization methods for finding positively invariant sets of ordinary differential equations

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The problem of deciding whether a polyhedral set is positively invariant is equivalent to the verification of a certain mathematical property (a containment relation) for all points of that set. In this talk we introduce a complete global search method based on interval arithmetic calculations, that is able to carry out this verification on a computer with mathematical guarantee. Namely, we show how transform the above containment problem into a set of global optimization problems for box-shaped sets, and solve them with an interval branch-and-bound algorithm. Furthermore, we introduce a method for finding boxes that are positively invariant for a given ODE and integration stepsize and an algorithm to find the maximal stepsize for which a given box is positively invariant. The applicability and efficiency of the methods are demonstrated on low-dimensional stiff chemical reaction models.

# Polynomial analysis of steering and braking interventions based on invariant sets

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The presentation proposes an analysis method for the intervention regions of steering and braking systems. In the method the actuators are formulated using first-order ordinary polynomial differential equations. In the analysis the maximum Controlled Invariant Sets of the systems are computed based on the Sum-of-Squares (SOS) optimization algorithm. The calculated sets represent the maximum region in state-space, in which the motion of the vehicle can be stabilized. The application of the set-based analysis is a novel viewpoint in vehicle dynamics, which has an impact on the design of actuator selection strategy and the coordination of vehicle controllers.

# Autonomous drive of commercial vehicles as contributor to GHG emission reduction - platform systems and their control

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After the successful implementation of the EURO6 requirements, the European Union turns its attention to reduce the greenhouse gas (GHG) emission. In the field of transportation, the most important component is the reduction of the CO2, which means, at the final end, reduction of fossil fuel consumption, especially for road vehicles. There are different means of doing so, definitely the electrification of the vehicles 'driveline is one the chief opportunity. Besides, there are other opportunities, depending on the driving condition and environment of the vehicle, where major contribution to CO2 reduction can be achieved and, at the same time, other characteristic of the transport will be improved, such as utilization of road infrastructure, reduction of traffic incidents and fatalities on the road. The paper reports about recent developments in this field for heavy commercial vehicles, which systems enable – with appropriate modifications – the driverless operation, which is basic condition for operation modes such as platooning, lane keeping or automatic maneuvering in closed areas. Several aspects of the safety criticality level of the related vehicle dynamic systems (steering and braking) together with some aspects of the sensor fusion will be discussed. Also the interplay between these systems will be discussed.

# Computational intelligence driven integrated traffic management and air quality control using space services

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Urban transport is currently unsustainable. The use of cars has increased and urban environments are in dire need of new planning and management methodologies to keep traffic flowing. iTRAQ – Integrated Traffic Management and Air Quality using Space Services is a European Space Agency funded project led by a consortium of UK industry, academic and local authority partners. The consortium developed and validated a dynamic system for optimising the use of the road network balanced with the need to sustain high standards of air quality. iTRAQuses a number of inputs that enable it to sense the current situation in near-real-time and provide accurate forecasts using Artificial Neural Networks. The system then uses CI optimisation techniques together with the predictions to provide enhanced traffic and air quality management strategies.

# Measuring small scale differences of traffic caused air pollution in a street canyon

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Air pollution is the most important environmental impact of combustion engine drived vehicles. In European cities, road transport is the primary source of the most critical components of air pollution, especially nitrogen-oxides. For major cities long term monitoring data are available for the main pollutants, but the number of monitoring sites in a single city is usually very low. Inside city differences of exposition is rarely investigated, and mostly only by simulations or wind tunnel experiments. We performed a real scale fine resolution measurement in a narrow street canyon with high traffic. Daily profiles and spatial distribution of NOx emission was recorded and compared to manual traffic counting data. Detected inside-crossing-differences and high level of NOx concentrations suggest that pedestrians and inhabitants of particular sites are exposed to significantly higher concentration, then indicated by regular monitoring.

# Design and realization of FFNN-based neurocontroller for HEV

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In connection with the previous results in this research phase we developed a neurocontroller for controlling the HEV, which is a nonlinear MIMO-system. The SM-controlled stable vehicle-model (in simulink) was available for gathering the input/output data-pairs, which are necessary in realizing the neurocontroller. For this purpose the basic reference speed sub-model has been augmented with a band-limited white-noise based driving cycle, and also with a random number generator and random integrator based driving cycle. Both the prototype vector and the target vector contain not only the gathered vectors, but they have been concatenated with their differences, respectively. Finally, an FFNN neural network with two hidden layers has been trained, and successfully integrated into the existing HEV-model in simulink. For testing purposes, the basic reference speed sub-model has been augmented with several new driving cycles, and based on these detailed tests it can be concluded, that the FFNN-based neurocontroller's performance is acceptable in most driving cycles, however the SM-controller over-performs it.

# How difficult is nonlinear optimization?

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Nonlinear optimization (NLO) - including both global and local scope optimization - covers a vast range of problems, from trivial to practically intractable. Therefore, strictly speaking, it is impossible to offer "guaranteed" advice to NLO software users. This fact becomes especially obvious, when facing unusually hard and/or previously unexplored challenges. For example, we mention advanced NLO applications arising in the context of environmental engineering (Deschaine, Lillys, and Pintér, 2013; Pintér and Satish, 2014); experimental design for engineering optimization (Pintér and Horvath, 2013); financial modeling and optimization (Caglayan and Pintér, 2013); object packings and related logistics issues (Castillo, Kampas, and Pintér, 2008; Fasano and Pintér, 2013; Pintér and Fasano, 2014); and great many other areas not listed here (consult e.g. Pintér, 1996, 2002, 2006).

Motivated by such practical demands, significant efforts have been devoted to NLO software testing and benchmarking since decades: consult e.g. the recent studies by Pintér and Kampas (2013), Rios and Sahinidis (2013), Hatwágner and Pintér (2014), with numerous further topical references.

In this talk, we offer a set of observations supported by computational results, obtained by solving a collection of widely used test problems. Our current model collection includes a set of academic test problems, but it is mostly based on a range of typical real-world optimization applications. We also included some scientifically relevant and often very difficult scalable optimization challenges. The entire test problem collection has been solved by current implementations of the LGO solver suite for global and local NLO (Pintér, 1996, 2009, 2014).

Based on our results, it is possible to offer careful guidance to LGO users and, arguably, also to other similar scope NLO software users. Our conclusions are related to the "expectably sufficient" computational effort to handle a range of NLO problems. We highlight the need for global vs. local optimization, and mention extensions of our current study towards mixed-integer NLO, as well as NLO under limited computational resources.

# On positive explicit peer methods of high order

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We discuss the construction of explicit general linear methods which preserve the positivity of the solution of certain initial value problems for sufficiently small step sizes. We restrict ourselves to peer methods which are characterized by high stage order. The methods we found by applying numerical tools for constraint optimization (FMINCON and NMinimize) to the SSP condition exhibit an interesting sparsity pattern. We have found positive methods up to order 13.

# Steplength thresholds for invariance preserving of discretization methods of dynamical systems

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Steplength thresholds for invariance preserving of three types of discretization methods on a polyhedron are considered. For Taylor approximation type discretization methods, we prove that a valid steplength threshold can be obtained by finding the first positive zeros of a finite number of polynomial functions. Further, a simple and efficient algorithm is proposed to numerically compute the steplength thresh- old. For rational function type discretization methods, we derive a valid steplength threshold, which can be computed by using the analogous algorithm in the first case, for invariance preserving. The relationship between the previous two types of discretization methods and the forward Euler method is studied. Finally, for the forward Euler method, the largest steplength threshold for invariance preserving is presented by solving a finite number of linear optimization problems.

# Guaranteed performance with analysis oriented KYP lemma

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Variants of the S-procedure provides an important tool in robust stability and robust performance design. This paper presents an analysis oriented analog of the full block S-procedure (extended KYP lemma), also extending its applicability, by relaxing the usual compactness assumption, allowing unbounded domains defined using quadratic multipliers. The prof of this result reveals the role of the more elementary variant of the S-procedure and gives us the opportunity to emphasize the role played by the theory of indefinite spaces and those constructions that reveals the "linear" aspects of different feedback control problems formulated in the linear fractional framework.

# Including the shaft position information in the model of an PMSM motor for sensorless control application

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Accurate modelling of PMSM needs considering the special geometry and nonlinear magnetic characteristics of machine parts. In this paper an analysis of a slotless surface mounted permanent magnet synchronous motor has been presented including mathematical modelling and measurement results. The electrical model has been extended with the effect of saturation and other measured phenomena on mutual fluxes; hence it becomes possible to detect the initial rotor position.

Keywords: Modeling, identification, sensorless methods, carrier-frequency injection, initial rotor position, magnetic polarity, saturation

# Optimum control strategy for vvhicle PMSM in field-wakening operation

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The flux weakening operation is an applied control of PMSM for extending the region over nominal speed. This paper deals with this question and its impacts. The proved method increases the torque angle and with this the d axis directed component of the stator current vector for reduce the main flux, but the loss and heat developing in magnets became significant. These impacts and its reduction need several investigations. Our work indicates the possibilities and limits of flux-weakening for a given PMSM, and a usable optimal control strategy applied on a 108 kW PMSM.

# Predicting flight arrival times with a multistage model

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Airlines are constantly looking for ways to cut flight delays, in order to enhance service quality and reduce operational costs. The goal of the data science contest, GE Flight Quest, was to make flights more efficient by improving the accuracy of arrival time estimates. The data set of the contest was 128 GB in size and contained 252 data columns arranged in 34 tables. This paper presents my solution that won third prize in the competition. My approach uses a multistage model, consisting of consecutive ridge regressions and gradient boosting machines, built on 56 features constructed from the raw data.

The hardware environment used for training and running the model was a 64 core machine with 1 terabyte of memory.

# Resolution of kinematic constraints via local optimization in an adaptive dyanamic control of an electric cart

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In the dynamic control of castor-supported double-wheeled carts the controller has to tackle the kinematic contraint of these dveices as follows: while the user generally wishes to control 3 independent data i.e. the (x,y) koordinates of the center point of the cart on a plain as well as its orientation (rotation around the horizontal axis) only two control signals, the torques of the driving wheels can be set physically. The task is further complicated by the imprecise dynamic model of the cart availbale and the unknown external disturbances. In the sugested solution a local optimization is apllied by the use of which the appearance of the Riccati equations can be avoided. The adaptive controller is designed by the methodology based on the application of "Robust Fixed Point Transformations (RFPT)" that allows the separation of the kinematic formulation of the desired trajectory tracking behavior and its dynamic realization. It is shown via simulations that the purely kinematically formulated tracking kompromise and the novel adaptive control design can successfully cooperate.

## Data fusion concept for urban traffic estimation based on heterogeneous data

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In the last few decades, information technology has developed rapidly. Several new technologies have been introduced in the field of Intelligent Transport Systems as well. In our days, a plenty of road traffic related data are available or even continuously collected. This information worth processing for further use, e.g. to provide reliable traffic estimation. The available data, however, arrive typically from inhomogeneous sensor systems. Consequently, a proper data fusion concept is introduced based on the well-known Switching Kalman Filter. The proposed method enables efficient travel time estimation for urban road traffic network.

## Research and development of vehicles' driving systems for sustainable city traffic

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The development of green vehicles' driving system has to be started with the determination of special requirements. Using these, research and development can be done on a system and some parts (motor, motor control, battery pack and vehicle control) with the "V" form as usual. The first stage of the optimization can be some cycles of the development iteration process(es) introduced in the article.

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# Notes

**Basic research for the development of hybrid and electric vehicles**
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**„Smarter Transport" IT for co-operative transportsystem**
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**Cooperation between higher education, research institutes and automotive industry**
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