JÁRMŰIPARI KUTATÓKÖZPONT
RESEARCH CENTER OF VEHICLE INDUSTRY

2nd WORKSHOP ON DESIGN, SIMULATION, OPTIMIZATION AND CONTROL OF GREEN VEHICLES

22-23 September, 2014
Győr, Hungary

SZÉCHENYI ISTVÁN UNIVERSITY

WELCOME

Dear DSOC Participant,

we welcome you on the 2nd DSOC workshop at the Széchenyi István University in Győr!

This second workshop is the closing event of our project entitled "Basic research for the development of hybrid and electric vehicles" running at the Research Centre for Vehicle Industry of Széchenyi István University, Győr, Hungary under the grant TÁMOP-4.2.2.A-11/1/KONV-2012-0012.

In this project we perform research to solve some of the challenges of green vehicles faced by modern society. More specifically, the conference themes are focused on design and the development of electric motors for vehicles.

The engineering goals cannot be achieved without using the methods of mathematical modelling, computer simulation, optimization and control, which combined have recently become one of the key enabling technologies of the industry. Within the themes the scientific background and application of this technology concerning electric vehicles should be presented. In order to support this aim and assist young and new researchers of the fields, some tutorials have been organized as part of the workshop.

Main topics:

- Green Vehicle concepts
- Design, simulation and optimization of PMS motors for vehicles
- Invariant sets for dynamical systems
- Vehicle dynamics control
- Driveline optimization for vehicles

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

Kind regards,

2nd DSOC Workshop Organizers

József Bokor László Palkovics Zoltán Horváth

Péter Gáspár Zoltán Varga

USEFUL INFORMATION

WIFI:

Bridge
Network: bridge
Password: drotnelkul20080905

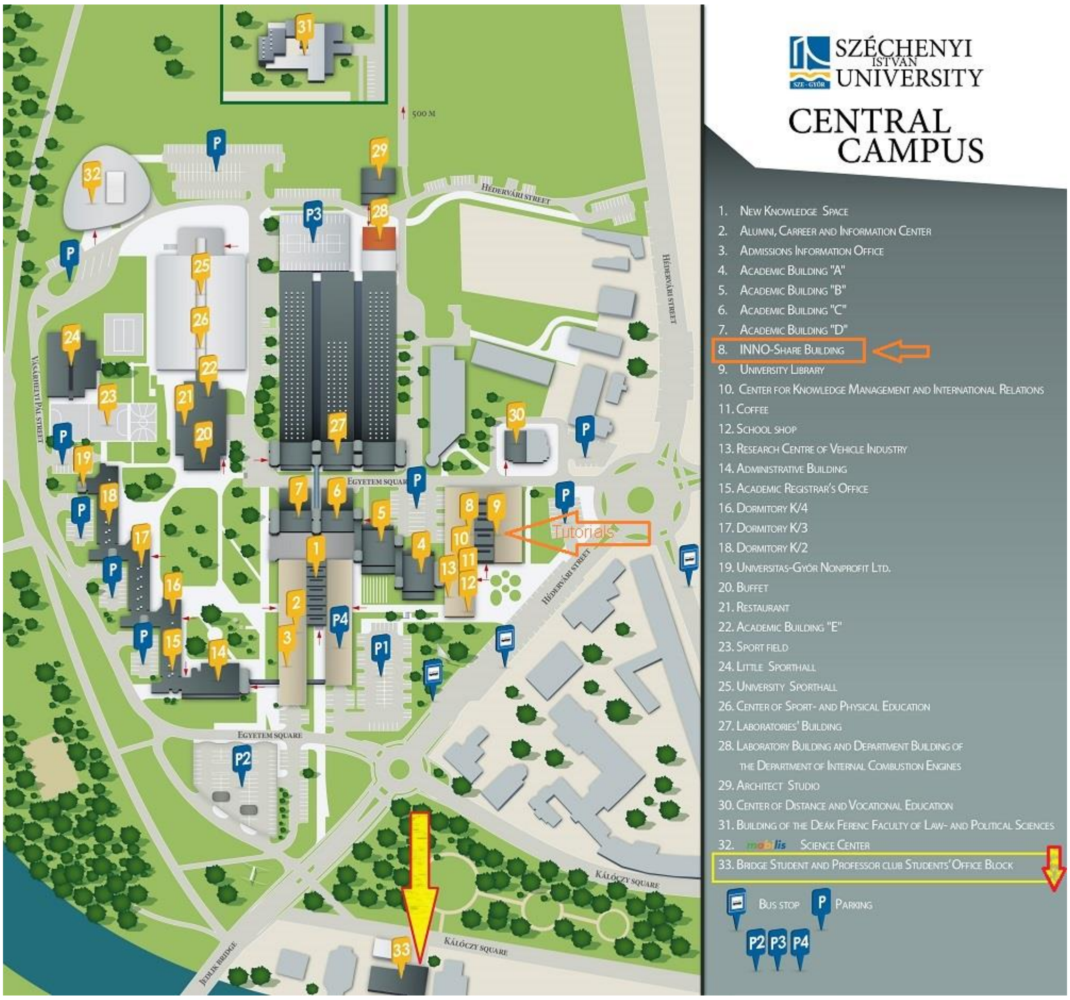
INNO-SHARE Building
Network: IS-WLAN
Password: tudomanyoskutatas

Campus:

The **lectures** on the 22nd September take place at the Bridge Student and Professor Club first floor.

The **tutorials** on the 23rd September take place at the Research Center of Vehicle Industry - Inno-Share building 2nd floor

The **conference dinner** take place at Bridge Student and Professor Club terrace.



Links:

http://jkk.sze.hu/en_GB/2dsoc-site
http://uni.sze.hu/en_GB/home
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KEYNOTE SPEAKERS

BESTLE, DIETER (BRANDENBURG UNIVERSITY OF TECHNOLOGY, COTTBUS-SENFTENBERG)

- Title: Robust Design of Velocity-adaptive Control for an All-wheel Steering Car
- Date: 22 September, 2014 09:50 – 10:30

GLIELMO, LUIGI (UNIVERSITY OF SANNIO, BENEVENTO)

- Title: Robust Vehicle Stability Control via Set-Based Methods
- Date: 22 September, 2014 13:50 – 14:30

RIZZO, GIANFRANCO (UNIVERSITY OF SALERNO, SALERNO)

- Title: Energy Management of Hybrid and Hybridized Electric Vehicles
- Date: 22 September, 2014 09:10 – 09:50

SCHLÖDER JOHANNES (HEIDELBERG UNIVERSITY, HEIDELBERG)

- Title: Energy conservation in vehicle operation by solution of mixed integer optimal control problems
- Date: 22 September, 2014 13:10 – 13:50

TUTORIALS

BESTLE, DIETER (BRANDENBURG UNIVERSITY OF TECHNOLOGY, COTTBUS-SENFTENBERG)

- Title: Strategies for Multi-criterion Optimization and Robust Design
- Date: 23 September, 2014 08:30 – 10:30

RIZZO, GIANFRANCO (UNIVERSITY OF SALERNO, SALERNO)

- Title: Energy Management of Hybrid and Hybridized Electric Vehicles
- Date: 22 September, 2014 11:00 – 13:00

PROGRAM OVERVIEW

22 September, 2014

	Room: Bridge 1	Room: Bridge 2
	Chairman: Zoltán Horváth	
08:30-15:00	Registration	
09:00-09:10	József Bokor	
09:10-09:50	Gianfranco Rizzo	
09:50-10:30	Dieter Bestle	
10:30-10:50	Break	
	Chairman: Dieter Bestle	Chairman: Imre Czinege
10:50-11:10	Béla Lantos	Tamás Haidegger
11:10-11:30	Balázs Németh	Krisztián Kósi
11:30-11:50	Tímea Fülep	Gergely Bári
11:50-12:10	József K. Tar	Balázs Trencséni
12:10-13:10	Lunch break	
	Chairman: Zoltán Horváth	
13:10-13:50	Johannes Schlöder	
13:50-14:30	Luigi Glielmo	
14:30-14:50	Break	
	Chairman: Gianfranco Rizzo	Chairman: Johannes Schlöder
14:50-15:10	Zoltán Varga	Miklós Kuczmann
15:10-15:30	Imre Czinege	Abdelhakim Lotfi
15:30-15:50	Dávid Czeglédi	Péter Zsebők
15:50-16:10	István Szénásy	Márton Kuslits
16:10-16:30	Break	
	Chairman: Luigi Glielmo	Chairman: Alexandros Soumelidis
16:30-16:50	Zoltán Szabó	Péter Kőrös
16:50-17:10	Csaba Gáspár	Zoltán Szeli
17:10-17:30	Tihamér A. Kocsis	Bettina Kollár
17:30-17:50	Zoltán Horváth	Ádám Bakos
18:30-21:00	Conference Dinner	

23 September, 2014

	Room: Inno-Share - Workshop room
08:00 - 08:30	Registration
08:30 - 10:30	Dieter Bestle
	Strategies for Multi-criterion Optimization and Robust Design
10:30-11:00	Break
11:00 - 13:00	Gianfranco Rizzo
	Energy Management of Hybrid and Hybridized Electric Vehicles
13:00 - 14:00	Lunch break

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PROGRAM 22 SEPTEMBER, 2014

	Room: Bridge 1	Room: Bridge 2
08:30-15:00	Registration	
	Chairman: Zoltán Horváth	
09:00-09:10	József Bokor *Opening*	
09:10-09:50	Rizzo Gianfranco *Energy Management of Hybrid and Hybridized Electric Vehicles*	
09:50-10:30	Dieter Bestle *Robust Design of Velocity-adaptive Control for an All-wheel Steering Car*	
10:30-10:50	Break	
	Chairman: Dieter Bestle	Chairman: Imre Czinege
10:50-11:10	Béla Lantos *Time optimal control of four-in-wheel-motors driven electric cars*	Tamás Haidegger *Kinematic Design of Traceable Trajectories for Caster Supported WMRs Having Two Active Wheels*
11:10-11:30	Balázs Németh *Analysis and Control of Nonlinear Actuator Dynamics Based on the Sum of Squares Programming Method*	Krisztián Kósi *Simulation Tests of an RFPT-Based MRAC Controller for an Electric Cart for Various Trajectory Tracking Approaches*
11:30-11:50	Tímea Fülep *Robust Control of In-Wheel Electric Vehicles*	Gergely Bári *Conceptulaization of hybrid-electric vehicle drivetrain control*
11:50-12:10	*József K. Tar* *Generalized Dynamic Model of DC Motors Driven WMRs for RFPT-Based Order Reduced Adaptive Control*	Balázs Trencséni *Enhancement of hybrid-electric driveline control using predictive algorithms*
12:10-13:10	Lunch break	
	Chairman: Zoltán Horváth	
13:10-13:50	Johannes Schlöder *Energy conservation in vehicle operation by solution of mixed integer optimal control problems*	
13:50-14:30	Luigi Glielmo *Robust Vehicle Stability Control via Set-Based Methods*	
14:30-14:50	Break	

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PROGRAM 22 SEPTEMBER, 2014

	Chairman: Gianfranco Rizzo	Chairman: Johannes Schlöder
14:50-15:10	Zoltán Varga *The role of the transmission in electric driven vehicles*	Miklós Kuczmann *Electrical Machine Analysis by the Help of the Finite Element Method*
15:10-15:30	Imre Czinege *Mass Optimization of Gearboxes for BEVs*	Abdelhakim Lotfi *Multiphysics thermal analysis of a Permanent Magnet machine*
15:30-15:50	Dávid Czeglédi *Development of an electric driven city car*	Péter Zsebők Fast 3D simulation of PMSMs
15:50-16:10	István Szénásy *Some actual questions at the development of up-to date PMSM motors*	Márton Kuslits *Framework for multiobjective optimization of PMSM design for electric vehicle drive applications*
16:10-16:30	Break	
	Chairman: Luigi Glielmo	Chairman: Alexandros Soumelidis
16:30-16:50	Zoltán Szabó *All full-state robust qLPV controllers*	Péter Kőrös *Driver assistant algorithm for power loss reduction in light electric vehicles*
16:50-17:10	Csaba Gáspár *Some regularized versions of the method of fundamental solutions with applications*	Zoltán Szeli *Some possibilities for reducing energy consumption of electric-powered vehicles*
17:10-17:30	Tihamér A. Kocsis *Vehicle control with numerical methods*	Bettina Kollár *Development of an automated high performance electric motor test bench*
17:30-17:50	Zoltán Horváth *Set invariance of dynamical systems with applications*	Ádám Bakos *Designing system architecture and control of a small-scale electric vehicle*
18:30-21:00	Conference Dinner	

Program 23 September, 2014

Room: Inno-Share - Workshop room

08:00 - 08:30	Registration
08:30 - 10:30	Dieter Bestle Strategies for Multi-criterion Optimization and Robust Design
10:30-11:00	Break
11:00 - 13:00	Gianfranco Rizzo Energy Management of Hybrid and Hybridized Electric Vehicles
13:00 - 14:00	Lunch break

ABSTRACTS

Designing system architecture and control of a small-scale electric vehicle

Ádám Bakos, Alexandros Soumelidis, and Péter Gáspár
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An introduction to the design and realization process of a 1:5 scaled four-wheel electric vehicle using four in-wheel permanent magnet synchronous motor (PMSM) based electric drives is presented. The objectives of realization this type of system arise from the demand for a low-cost, easy to operate, and safe experimental platform that facilitates testing and verification of new ideas, new solutions, and developments emerging during research activities for advanced control methods in the field of electric vehicles. A versatile test platform has been intended to be realized, where several configurations (e.g. 2-wheel, 4-wheel drives with and without steering), several solutions and design methods for sensing, measurement, control, and fault detection can be tested under several conditions without the risk of causing any accident. In our presentation the system architecture, the construction, the mechanical, electrical, and electronic components are outlined including also the hardware and software aspects of the high efficiency embedded microcomputers used on-board, as well as main principles of control used to realize the basic tasks are concerned. A realization partially completed, built at the Systems and Control Lab of the Institute for Computer Science and Control (SZTAKI), will also be presented.

Personalized information services affecting mobility decisions and processes

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An effective improvement to increase vehicle efficiency is the hybridization of the vehicle's powertrain. In this presentation the main steps of the development process will be summarized from requirement definition over driveline concept decision to the control development. Different system architectures had been analyzed and one optimal had been selected according to specific market demands. More kind of control strategies had been elaborated and evaluated on appropriate vehicle model. The developed controllers had been compared to each other in SiL environment.

Robust Design of Velocity-adaptive Control for an All-wheel Steering Car

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Drivability of passenger cars may be improved by adding a proper rear steering strategy with velocity-adaptive control. This strategy is optimized in the frequency domain where the design objectives concern the response dynamics of lateral acceleration and yaw velocity. The design variables include both discrete variables for velocity independent parameters and shape functions for velocity-adaptive control parameters. The resulting bi-criterion optimization problem is solved with a multi-objective genetic algorithm.

Typically, such an optimization drives designs towards the borders of the feasible design space. However, in reality these designs cannot be manufactured as precisely as proposed or the system is exposed to changing environmental conditions. Then even small system changes will lead to infeasible or non-optimal system behavior. In order to account for such uncertainties, the objectives should be considered as random variables during the design phase already, and a robust design concept should be applied. Therefore, mean values are minimized to obtain best mean behavior, and variances are minimized to achieve best robustness against change of car parameters. The presentation will demonstrate the transition from the deterministic to the robust design problem formulation, and strategies for efficient solution.

Development of an electric driven city car

Dávid Czeglédi
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In the presentation I will show the design and construction of a double sitter electric drive city car, which was developed in the Széchenyi István University.

The audience learn about the purpose of the development, and the self-developed systems, and components: vehicle control system, on-board diagnostic and information system, electric motor control system, battery and battery management system.

Our vehicle is a very special city car, because we can easily build in the components from external manufacturer, and this components could work with own systems together.

The car has license plate number, and registered into the traffic in L7e category

Mass optimization of gearboxes for BEVs

Imre Czinege
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The driving system of Battery Electric Vehicles is very complex as it contains many different components, e.g., electric motor, transmission, power electronics, and battery. Each component needs to be designed properly in order to reach high efficiency. The paper is focusing on the volume and mass optimization of gearboxes used in electric vehicles. The most important material parameters are pitting bearing capacity and tooth root strength, which can be correlated with the gear pair parameters like center distance of gears and diametral pitch. Developing an actualized Ashby model for gear pairs, the minimum value of mass as function of material parameters and density can be calculated, and the gear materials can be classified. Analyses proved that case or induction hardened steels and titanium alloys with appropriate surface treatment are the best solutions for gearboxes.

Robust Control of In-Wheel Electric Vehicles

Tímea Fülep, Péter Gáspár, Zoltán Szabó, József Bokor
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The research proposes a 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 introduced. 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.

Some regularized versions of the method of fundamental solutions with applications

Csaba Gáspár
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Meshless methods have become quite popular in recent years, since they require neither domain nor boundary mesh structure, in contrast to the usual finite element modelling. To solve linear, homogeneous problems, the Method of Fundamental Solutions has spread worldwide, since it is not simply a meshless, but also a boundary-only technique, i.e. it needs some scattered set of boundary collocation points (without any mesh structure), but no internal points. In its original form, the method defines an approximate solution with the help of the fundamental solution shifted to some external (source) points. However, the resulting algebraic system of equations is severely ill-conditioned in general. If the sources are located along the boundary, singularities appear in the approximate solution, therefore the accuracy breaks down.

In this talk, some ideas that circumvent the problem of singularity are overviewed. Novel methods are also outlined. The main idea is to use an approximate fundamental solution which has no singularity at the origin; the stronger singularities due to the normal derivative of the fundamental solution are eliminated by solving a simple auxiliary subproblem. Both 2D and 3D problems are considered. The approach is generalized to 3D axisymmetric potential problems as well, resulting in a good compromise between the accuracy and the ill-conditioned character of the method. Some applications to heat transfer problems are also presented.

Robust Vehicle Stability Control via Set-Based Methods

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The design of a robust lateral stability controller to track yaw rate and lateral velocity reference signals while avoiding front and rear tire force saturation is presented. The controller takes into account the driver's intent at the design stage by treating it as a measured disturbance. The uncertainty in the driver's input is modeled as a set–valued function of the vehicle states. The control design is based on a hybrid piecewise affine bicycle model with input–dependent and state–dependent uncertainties. The performance of the controller and the importance of driver behavior modeling are demonstrated through experimental tests on ice with aggressive driver maneuvers.

Kinematic Design of Traceable Trajectories for Caster Supported WMRs Having Two Active Wheels

Tamas Haidegger, Krisztán Kósi, József K. Tar
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In the adaptive control of caster wheel-supported mobile robots driven by two active wheels underactuation and the presence of non-holonomic constraints make it impossible to exactly track an arbitrary trajectory formulated in the terms of nominal position in the (x,y) plane and nominal orientation. A possible problem solution may be the kinematic construction of the nominal trajectory, then the calculation of its best approximation allowed by the kinematic constraints, application of an available approximate dynamic model for the calculation of the necessary active actuating torque values, and some adaptive modification of the results of this calculation to improve the precision of trajectory tracking. In the case of Linear Time-Invariant (LTI) systems turning from a PD-type controller to a PID-type one normally improves the precision of the trajectory tracking. However, in our case it was experienced that that due to the remnant errors caused by the non-holonomic constraints a common PID type controller diverges therefore some modification of the kinematically prescribed trajectory tracking design becomes necessary. It was found that in the case of a Robust Fixed Point Transformations (RFPT) based adaptive, order reduced controller some limitation in the feeding back the integrated error improves the situation.

Furthermore, it was also found that by adding relatively small amplitude and high frequency "perturbation" to the nominal trajectory helps to improve the tracking precision by providing better compromise regarding the tracking precision for the nominal components. These statements are substantiated by simulation results.

Set invariance of dynamical systems with applications

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Positively invariant sets play an important role in the analysis of both continuous and discrete time dynamical systems. In addition, modelling physical processes, e.g. heat and mass transport problems, the physically admissible states form positively invariant sets, which are necessary to be preserved under numerical discretization methods. Moreover, several control methods are based on the positive invariance of sets.

In this paper we present our results on characterizing positively invariant sets. We present several constructions of positively invariant sets for continuous time problems employing results and methods of different fields of mathematics, namely linear algebra, linear optimation and interval methods for global optimization. In addition, we provide conditions on the discretization parameters of numerical methods that enable to preserve positive invariance of sets under discretization, in particular for linearly implicit methods and extremely high order peer methods. We apply our findings to numerical simulation of heat conduction and fluid flow problems.

This is a joint work with T.A. Kocsis, T. Terlaky, Y. Song, M. Markót, H. Podhaisky and R. Weiner.

Vehicle control with numerical methods

Tihamér Albert Kocsis, Zoltán Horváth, Adrián Németh
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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.

Development of an automated high performance electric motor test bench

Bettina Kollár, Gábor Szakállas
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The electric drives are widely used nowadays. In the Research Center of Vehicle Industry we also deal with this area, so it became appropriate for us to develop an electric motor test bench to investigate and test our own designed electric motors and motor controllers in a wide range of power.

The energy efficiency was important at the design of the power supply system. There is direct exchange of energy between motor-driven and regenerative-driven inverters, only the losses are taken from the power supply.

We used commercially available instruments to design the measuring system. We chose highly accurate and high bandwidth transducers, which are able to measure the high-frequency phase currents and voltages and hereby the efficiency of the motors and inverters.

A central control unit makes the control and the data acquisition of the test bench, which runs a real-time operation system.

The preliminary specifications and the phases of implementation of the electric motor test bench will be presented in the following areas: mechanical conformation, power supply system, measurement system and control system.

Simulation Tests of an RFPT-Based MRAC Controller for an Electric Cart for Various Trajectory Tracking Approaches

Krisztián Kósi, Tamás Haidegger, József K. Tar
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Beside guaranteeing precise trajectory tracking the main purpose of Model Reference Adaptive Controllers (MRAC) is the generation of an "illusion" for an external control loop regarding the dynamic properties of the system under control. The practical need for such an illusion may be of different origins: either guaranteeing the "nominal parameters" of the system under control, or simply making the control easier for the external control loop by feeling that the system to be controlled has "simple" dynamic properties may be reasonable. It is worth noting that the "external loop" may be realized by the sensory and motoric system of a human driver, too. It was shown in the previous lecture that the control of a WMR of unknown dynamic parameters necessarily is a nonlinear problem further burdened by underactuation, non-holonomic constraints for the solution of which the Robust Fixed Point Transformations (RFPT)-based adaptive control was found to be applicable. The aim of this contribution is to show via simulation results that the RFPT-based MRAC controller can be also realized in order to ease the work of a potential human driver or any other controller designed by simple methods for the external loop.

Driver assistant algorithm for power loss reduction in light electric vehicles

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Nowadays the fully electric vehicles powered by PMSM or ASM are spreading. These machines have ideal characteristics for driving. Our aim was to develop a control algorithm which reduces the power losses during the operation. We used measurements and simulation tool chains to reach our goal.

First step was the measurement of our PMSM and motor controller efficiency map. With this map we can calculate the current operating point properties. We made our powertrain model in AVL CRUISE and the car model in IPG CarMaker. After this step we had the basic tool chain to develop our control algorithm. If we would like to drive these electric powered vehicles with least power losses, then we must use the electric machine in the maximum efficiency operating regions.

When we planned the controller our goal was that the driver does not feel the control algorithm operation. So our control algorithm can modify the load signal between limits. We tuned the parameters of the controller with own developed MATLAB function. After the tuning we tested the controller with IPG CarMaker. When the controller was active then the energy consumption was decreased about 4 percent under test circumstances.

We would like to implement the controlling algorithm on our light weighted test vehicle on CompactRIO architecture.

Electrical Machine Analysis by the Help of the Finite Element Method

Miklós Kuczmann
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This presentation shows a finite element based environment for the simulation of two dimensional electromagnetic field problems, especially electric motors. The graphical user interface, the finite element mesh generator and the computational functions are free software tools that have been developed by scientific teams from all over the world. The GMSH has been used as mesh generator, the functions of PETSc have been used to realize finite element solution of the problems, finally the results have been presented in the frame of GMSH. The aim of this work is to realize a new software environment that can be used in the simulation of two dimensional problems as well as in education. In the case of electrical engineering applications, the Maxwell's equations must be solved by the help of potential formulations. To realize appropriate loss simulations, a dynamic vector hysteresis model must be implemented in the code. The system of nonlinear equations has been solved the iterative fixed point technique.

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Framework for multiobjective optimization of PMSM design for electric vehicle drive applications

Márton Kuslits, Istenes György, Miklós F. Hatwágner, Bettina Kollár
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Application of hybrid electric and battery electric vehicles is spreading nowadays. Passenger cars, light vehicles, utility and public transport vehicles are the most common application areas for electric drivelines. These applications, however, can be very different in characterization of electric machines, respectively the technical properties like size, weight, nominal speed and power, etc.

This broad variety of applications demands more and more precisely tailored electric machines in order to improve efficiency and reduce weight and cost. In order to fulfil this demand a possible approach is to apply multiobjective optimization methods during the design of electric machines for certain vehicle drive applications.

As an optimization case study, a simple outer rotor PMSM design optimization was implemented.

As first step, a multiobjective 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 this objective criterion. The cost function calculates the total machine weight and magnet weight also, since further objectives are minimizations of these values.

The optimization process was performed by sampling the cost function with different sampling strategies in the parameter space which is spanned by 6 geometrical parameters of the investigated PMSM. Based on the results, the Pareto front was calculated from which an optimal solution can be chosen according to the application requirements.

Time optimal control of four-in-wheel-motors driven electric cars

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The paper deals with the time optimal control of automatically driven electric cars in a test path between corridors under state and input constraints. The car is required to avoid a static obstacle or performing double lane change. The problem can be formulated as a dynamic nonlinear optimal control problem (DNLOCP). The resulting DNLOCP is solved by reformulating it to a static nonlinear program (NLP) using time discretization and direct multiple shooting method. Non-commercial open software packages are applied that substantially use the gradients of the objective function and the Jacobians of the constraints exploiting sparsely.

A novel algorithm and implementation is presented for computing the derivatives of the complex state trajectory joining equations. This algorithm was given in the form of matrix differential equations whose structure allowed computing their solution using RK4 in matrix form.

A novel method is presented to convert the optimal solution obtained using single-track (bicycle) model to the optimal control of four-in-wheels-motors driven (4WD) cars. The conversion assures similar motion of the COG of both models and optimal distribution of the longitudinal wheel forces.

The elaborated method can form the basis to generate an offline database of a central time optimal general collision avoidance system (CAS) for varying path parameters on a grid which can support real time applications.

Index terms: Time optimal control, Vehicle model, Direct multiple shooting, Sparse gradient and Jacobian, 4WD actuators, Optimal wheel force distribution, Collision Avoidance System

Multiphysics thermal analysis of a Permanent Magnet machine

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The aim of this study is to present a magneto-thermal analysis of an external-rotor permanent magnet synchronous machine based on finite element method. The developed model can be used to predict temperature distribution inside the studied motor during the rated operation. Electromagnetic computation is carried out with the aid of two 2D finite-element (FE) simulations on the cross-section of the PM motor. In addition, the magnetic core losses of the stator and rotor are modelled based on the results from the electromagnetic analysis and a post-processing formula based on the loss-separation principle. After the loss calculation, the temperatures of the machine are calculated by using 3D finite element method. The results obtained by the model are compared with experimental results from testing the prototype electric motor.

Analysis and Control of Nonlinear Actuator Dynamics Based on the Sum of Squares Programming Method

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The paper analyses the reachability characteristics of the brake system in order to determine its abilities for the entire vehicle system. The method is based on the nonlinear polynomial Sum-of-Squares programming method, in which the shape of the reachable set of the brake is calculated. Since the method can be applied to other actuators, a theory-based structure can be built for the coordination and reconfiguration of the actuators. The method is illustrated at various velocities and road conditions.

Energy Management of Hybrid and Hybridized Electric Vehicles

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In the last period, Hybrid Electric Vehicles (HEV) have been intended as real substitutes to engine-driven vehicles, in order to reduce fuel consumption and emissions. However, their market share is still limited as well as their influence on global fossil fuel demand and CO2 production. Therefore, the possibility of upgrading conventional vehicles to hybrid electric vehicles is gaining interest, as a feasible short-term solution.

After a general introduction on current and future sustainable transportation issues, the main methodologies available for the energy management of Hybrid Electric Vehicles are reviewed. Then, the lecture focuses on the hybridization of conventional vehicles and on the features of the Through-The-Road HEV's. Aspects related to optimal energy management and control, to drivability and to the integration with photovoltaic source for hybridized vehicles are presented and discussed, also starting from the current research work performed on such topics at the University of Salerno.

Energy conservation in vehicle operation by solution of mixed integer optimal control problems

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Energy optimal operation of vehicles like trucks or subway trains often requires the offline and real-time numerical solution of state and control constrained optimal control problems with both continuous and integer controls.

In the talk, two rigorous mathematical solution approaches, powerful numerical methods and practical applications for this class of problems are described.

The indirect approach based on Pontryagin's Maximum Principle and the Competing Hamiltonians algorithm leads to intricate multi-point boundary value problems in state and adjoint variables with jumps and switching conditions possessing difficult stability properties. An expansion of the adjoint variables and the local optimization of the Hamiltionian can be exploited to construct optimal feedback strategies even in case of integer controls.

A direct approach based on outer convexification, relaxation and the Krein-Milman theorem allows for offline solution of mixed integer control problems with no integer gap while avoiding the combinatorial explosion of computing time. Moreover, arbitrarily good approximations by integer solutions with finitely many switches can be constructed by adequate rounding procedures. Based on these offline solutions fast optimal feedback strategies are developed using Real-Time-Iterations for Mixed-Integer Nonlinear Model Predictive Control.

Advanced Multiple Shooting methods for the numerical solution of the intricate boundary value problems as well as optimization boundary value problems in both the indirect and the direct approach are described.

Applications to energy optimal operation in long-distance drives of heavy duty trucks and cam-controlled subway trains in the New York subway system demonstrate the high potential for energy conservation.

The talk is based on joint work with Hans Georg Bock, Christian Kirches, Richard W. Longman and Sebastian Sager.

All full-state robust qLPV controllers

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As an extension of the robust Hinf method, the time domain design based on linear matrix inequalities (LMI) is an appealing and conceptually simple framework to obtain robust qLPV controllers. This presentation provides a numerical reliable method to compute and parameterize all LPV controllers that corresponds to a given multiplier matrix.

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Some possibilities for reducing energy consumption of electric-powered vehicles

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The internal combustion engine vehicles are the significant part of road transport, however the number of electric vehicles are increasing. In order to reduce environmental pollution we need to emphasize importance of the development of electric vehicles. As for the internal combustion engines, a significant aspect to reduce the electric vehicle power consumption and energy usage. Most of the vehicles have limited battery capacity utilization in order to protect the batteries. Generally cheaper passive cell balancing solutions used which increases the temperature for built-in systems and the amount of charge energy, and thus consumption of the vehicle. This study aims to show how to develop an advanced battery protection for the vehicle to take advantage of the maximum capacity, without any damage. To reduce power losses, it is necessary to improve the motor controller power amplifier. The study also describes a simulation supported efficiency improving design of a low-power PMS motor controller power amplifier.

Some actual questions at the development of up-to date PMSM motors

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In permanent magnet motor's rotor, the permanent magnet demagnetization is a special fault type. The main reason of this demagnetization is the armature reaction induced by high temperature or/and large current, especially the armature reaction under the big torque condition, and big current by the short circuit of the inverter and the stator winding faults, and overload current.

Overload operation will produce large current higher than the rated one for several times, it will produce very big reverse magneto-motive force which will have strong demagnetization to permanent magnets increasing the demagnetization probability.

A permanent magnet can be damaged, i.e. losing all or a part of its remanent flux density, if the magnet is exposed to a high flux in the opposite direction of the magnet's magnetization. Risk of irreversible demagnetization is present if the outer-acting flux lowers than the flux density in the magnet.

Our investigations deal with a 110 kW and 1000 Nm performance PMSM motor's demagnetizations possibilities and determining the domain of flux-weakening operation without risk of demagnetization.

Generalized Dynamic Model of DC Motors Driven WMRs for RFPT-Based Order Reduced Adaptive Control

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In this presentation the practical problems related to the adaptive dynamic control of caster supported mobile robots driven by two DC motors- actuated active wheels are considered. This task suffers from different difficulties: 1) our system is underactuated since we wish to control three independent variables simultaneously, namely the position in the (x,y) plane and the orientation of the cart, while we have only two control agents, the torque values exceeded by the motors; 2) due to the inductance in the electrodynamic sub-system the motor torque cannot be set instantaneously: only its time-derivative can be abruptly set by setting the control voltage; 3) if no skidding or sliding on the (x,y) plane is allowed the motion of the system has to satisfy the non-holonomic constraints, too; 4) if the cart carries some work piece the dynamic parameters of the cart+burden system can be considered uncertain in the sense that for a model-based controller only approximate dynamic model is available; as a consequence the dynamic model of the cart cannot be based on tracking the motion of the mass center point and the rotation around this point with respect to an inertial frame that leads to LTI type dynamic equations of motion; due to this uncertainty it must be assumed that the tracked point is different to the mass center point that leads to coupled non-linear differential equations with uncertain parameters. Consequently the practically occurring control task is far more complex than the popular paradigms often considered in the literature. The aim of the presentation is to show that the special property of the RFPT-based adaptive controllers, namely that it separates the design of the kinematic and dynamic aspects of the desired control makes it possible to simultaneously solve the above problems without the use of the complicated Lyapunov function-based techniques. In the contribution simulation results made by the use of the SCICOS-XCOS free software are presented.

Enhancement of hybrid-electric vehicle drivetrain control

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The effectivity of vehicle powertrains may be improved by utilizing the potential energy due to road topography. To achieve such an improved energy-management function the navigation system can provide data of the road ahead the vehicle. In case of hybrid-electric vehicles a predictive energy-management algorithm can be overproportional beneficial because of the feasible on-board energy storage. Based on the evaluation of different types of driveline controllers, a new controller architecture have been developed and implemented into SiL environment.

The role of the transmission in electric driven vehicles

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Electric driveline=motor+gearbox or motor only? Driveline's requirements of electrical road vehicles. The necessity of gear at electric driving. Optimization motor and gearbox separately. Rough transmission system analyses. Possible variations of gearboxes and arrangements at electric driving: different vehicles and various transmissions. Main quantities at the gearbox analyses: speed and torque ratio, losses/efficiency, mass, volume/space, noise, duration, manufacturing, recycling.

Driveline arrangements: hub drive, wheel drive with propeller shaft, central drive with differential.

Concentrating on a special area: analyses and measurements of city car transmissions.

Fine analyses on the chosen system: measurements, analyses, optimization.

Parameter and loss measurements at middle and low load conditions on different types of transmissions. Mass and cumulated loss optimization of spur-gear and planetary gear transmissions.

Future target: connecting motor and gear, optimization of the motor – gear system using the results of the separately made optimizations.

Fast 3D simulation of PMSMs

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It is important at the development of PMSM to create the best option and this recommend to inspect more variants. This is required also more and more prototypes what can really slow down the development phase. The computational simulation and optimization cycles are great tools for create virtual prototypes. By using these tools, developers can find the best model variant without building a real prototype.

The task was to create a rotating simulation of the PMSM. The standard transient method for simulate a full 3D model takes years to get only one result, because of the complexity of the geometry. This work describes a computational study of a fast linked methodology.

Mainly the 2D simulation is enough to get results, but when the 3D flow affect the heat transports from the main heat sources like winding, than the 3D simulation will give realizable result. In addition the winding is an anisotropy component with perpendicular direction to the 2D plane. Our methodology can represent fast the distribution of temperature field and flow field. We linked ANSYS Maxwell, ANSYS Design Modeler, ANSYS Mesher and ANSYS Fluent software. They handle the modification of the geometry and update the next simulation component really fast. The calculations run as double precision solver on 16 computer processors.

We achieved with this cycle that it takes approximately 1-2 hour from the geometry changes to the computed result as steady state on a smooth 1250000 elements mesh. We also reduced the computational time for one revolution of the motor from the original 6-8 day to 15 minutes by transient analysis.

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NOTES

Basic research for the development of hybrid and electric vehicles

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