5th IFAC Conference on Engine and Powertrain Control, Simulation and Modeling

Final Program

Sept. 20-22, 2018, Changchun, China

Contents

Welcome Message

It's our great pleasure to welcome you to the 5th International Federation of Automatic Control (IFAC) Conference on Engine and Powertrain Control, Simulation and Modeling (E-CoSM 2018) which will be held in Changchun, China during September 20-22, 2018.

E-CoSM is an international conference organized under the auspices of IFAC in the field of vehicle control and intelligence which has great professionalism and authority. It is held every three years. After four successful editions organized and hosted by the Institut Francais du Petrole Energies Nouvelles (IFPEN) in France and Center for Automotive Research and SIM Center, The Ohio State University in USA, E-CoSM 2018 will for the first time be held in China, as well as in Asia. The conference is sponsored by the IFAC Technical Committee on Automotive Control and organized by the State Key Laboratory of Automotive Simulation and Control (ASCL), Jilin University and Technical Committee on Vehicle Control and Intelligence (VCI).

You will find that the rich program includes plenaries in the field of vehicle control and intelligence: 1. System modeling and simulation frameworks for engine and powertrain control design, validation and calibration. 2. Model-based control, estimation and diagnostics for the new generations of CI and SI engines and their exhaust gas aftertreatment. 3. Modeling, optimization and control for hybrid and electrified vehicles and their components. 4. Thermal management for next generation vehicles. 5. Control design for 2WD, 4WD and high mobility multipurpose wheeled vehicles. 6. Applications of intelligent technologies to vehicle powertrains for supervision, energy management and diagnostics type.

With about 190 papers submitted from 645 authors (more than 18 countries), we organized 570 reviewers to participate in the technical assessment of the submitted papers. As a result, around 470 reviews were received, which leads to the acceptance of 174 papers constituting the final program of E-CoSM 2018.

The technical program covers the same topics as the plenaries, but is not limited to them. There is a set of 28 sessions over the days, ranging from high level vehicle management control and supervision to detailed combustion control and estimation. An industrial program and series of pre-conference workshops will also be held as significant parts of the conference to increase the industrial participation and communication between industry and academia.

On behalf of all the Committee members, we sincerely look forward to welcoming you in Changchun, China.

Kind regards,

Hong Chen, General Chair

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Tielong Shen, IPC Vice Chair

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Sponsor

IFAC TC 7.1. Automotive Control

CAA Technical Committee on Vehicle Control and Intelligence

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IFAC TC 4.5. Human Machine Systems

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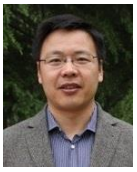

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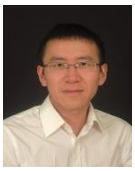

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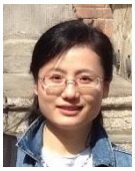

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General Information

Time: Sept. 20-22, 2018

Venue: South Lake Hotel, Changchun, China

Agenda: Sept. 20-22, 2018, academic lectures and discussion (including industrial forums)

Official Languages: English

Registration

All conference attendees must register. Personal badges will be provided to identify registered participants. Packet pick-up for advanced registrants and on-site registration will be available at the registration desk, which will be located at the hall of main building, South Lake Hotel.

The registration desk is open from Sept.19 to Sept.20. Hours of operation of the registration desk are as follows:

Sept.19, 13:00–22:00

Sept. 20, 7:30–18:00

Out of registration time, please contact the Registration Chair:

Jiangyan Zhang, Tel: (+86) 181-0411-0885, E-mail: zhangjy@sophia.ac.jp

Registration fees are shown in the table below.

Category	Early Registration	Regular Registration	Later & On-site Registration
Deadline	**August 10**	**September 10**	**September 22**
Full Registration	**480 USD**	**530 USD**	**580 USD**
Student Registration	**300 USD**	**300 USD**	**300 USD**

On-site Student Registration should be confirmed with a student ID. Extra banquet tickets can be purchased for 50 USD. All registered participants receive admission to welcome and farewell receptions; and one set of conference proceedings on a flashdrive. Extra proceedings (USB) can be purchased for 20 USD.

Oral Presentation Instructions

Oral Presentation Time: **20** minutes (including discussion; each speaker is required to meet his/her session chairs in the corresponding session rooms **15** minutes before the session starts and copy the slides to the computer; each session room is equipped with a projector and a PC (with Microsoft Windows, Microsoft PowerPoint 2013 and Adobe Acrobat). Please make sure that your files are compatible and readable with our operation system by using commonly used fonts and symbols.

Oral Session Chair(s) Instructions

The chair and/or co-chair are expected to:

Come to the session room at least 15 minutes before the session starts and stay until the end of the session;

Ensure with the volunteer in charge of the room that the presenters have no technical to contact their computers and use the screen;

Check if at least one speaker is present for each contribution and check their names and affiliations. In the case of a no-show, maintain the initial schedule; No-shows should be mentioned to the organization of the conference by using the session form;

At the beginning of each talk, recall its total duration, introduce the speaker. Comply with the timing by notifying the presenter

a few minutes before the end of the time slot;

At the end of the session, acknowledge all the speakers and audience, and close the session. Fill in the session form and give it to the volunteer in charge of the room.

Contacting the Organizing Committee:

Conference Contacting Email: hchen@jlu.edu.cn

Contacting Person: Gao Bingzhao, Jilin University, China

Tel: (+86) 138-4401-1557

E-mail: gaobz@jlu.edu.cn.

Contacting Person: Gao Jinwu, Jilin University, China

Tel: (+86) 155-8414-4693

E-mail: gaojw@jlu.edu.cn

Web Information:

The website of IFAC E-CoSM 2018:

https://www.ascl.jlu.edu.cn/ecosm2018

The website of Conference Paper Management System:

https://ifac.papercept.net/conferences/scripts/start.pl

The website of Technical Committee on Vehicle Control and Intelligence:

https://www.ascl.jlu.edu.cn/vci

Pre-conference Workshops (free):

Time: Sept. 19 (8:30-11:50, 14:00-16:10)

Venue: Nanling Campus, Jilin University

Contacting Person: Shuyou Yu, Jilin University, China

Tel: (+86) 135-0440-9392

E-mail: shuyou@jlu.edu.cn.

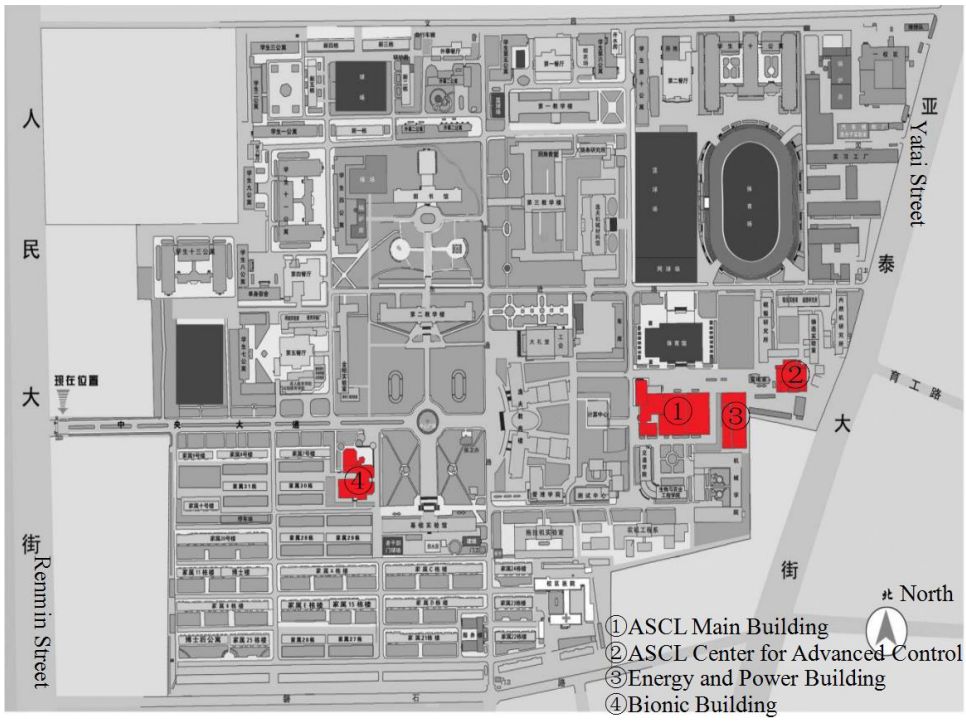
Venue, Date and Transportation

Venue Location

South Lake Hotel: the venue for conference from Sept. 20 to 22, 2018

Location of South Lake Hotel

Nanling Campus of Jilin University: the venue for Pre-conference Workshops on Sept. 19, 2018 and Lab Tour on Sept. 21, 2018



Location of Nanling Campus of Jilin University

Transportation

1. Changchun Longjia International Airport CGQ→South Lake Hotel

Route 1: Airport Bus+ Taxi

Get on the Airport Bus Line 1 at Changchun Longjia International Airport (to People's Square) → Get off the bus at People's Square Station → Get on the taxi at People's Square → Get off the taxi at South Lake Hotel.

Fare: about 40RMB

Route 2: Train+ Subway

Get on the Train at Longjia Station → Changchun Railway Station → Get on the Subway line 1 at Changchun Railway Station (N.) (Exit A） → Get off the subway at GONGNONG Square (Exit D） → Walk 1.1 km to South Lake hotel, about 18 minutes.

Fare: 11.5 RMB

Route 3: Taxi

Get on the taxi at Changchun Longjia International Airport，get off the taxi at South Lake Hotel .

Fare: about 120 RMB

2. Changchun Railway Station→South Lake Hotel

Route 1: Subway line 1

Get on the subway at Changchun Railway Station (N.)(Exit A)→ Get off the subway at GONGNONG Square (Exit D) → Walk 1.1 km to South Lake hotel, about 18 minutes.

Fare: 3 RMB

Route 2: Bus

Get on the 6 bus at Changchun Railway Station (South Square) → Get off the 6 bus at South Lake Hotel Station.

Fare: 1 RMB

Route 3: Taxi

Get on the taxi at Changchun Railway Station，get off the taxi at South Lake Hotel.

Fare: about 24 RMB

3. Changchun West Railway Station→South Lake Hotel

Route 1: Taxi

Get on the taxi at Changchun West Railway Station，get off the taxi at South Lake Hotel.

Fare: about 30 RMB

Route 2: Bus

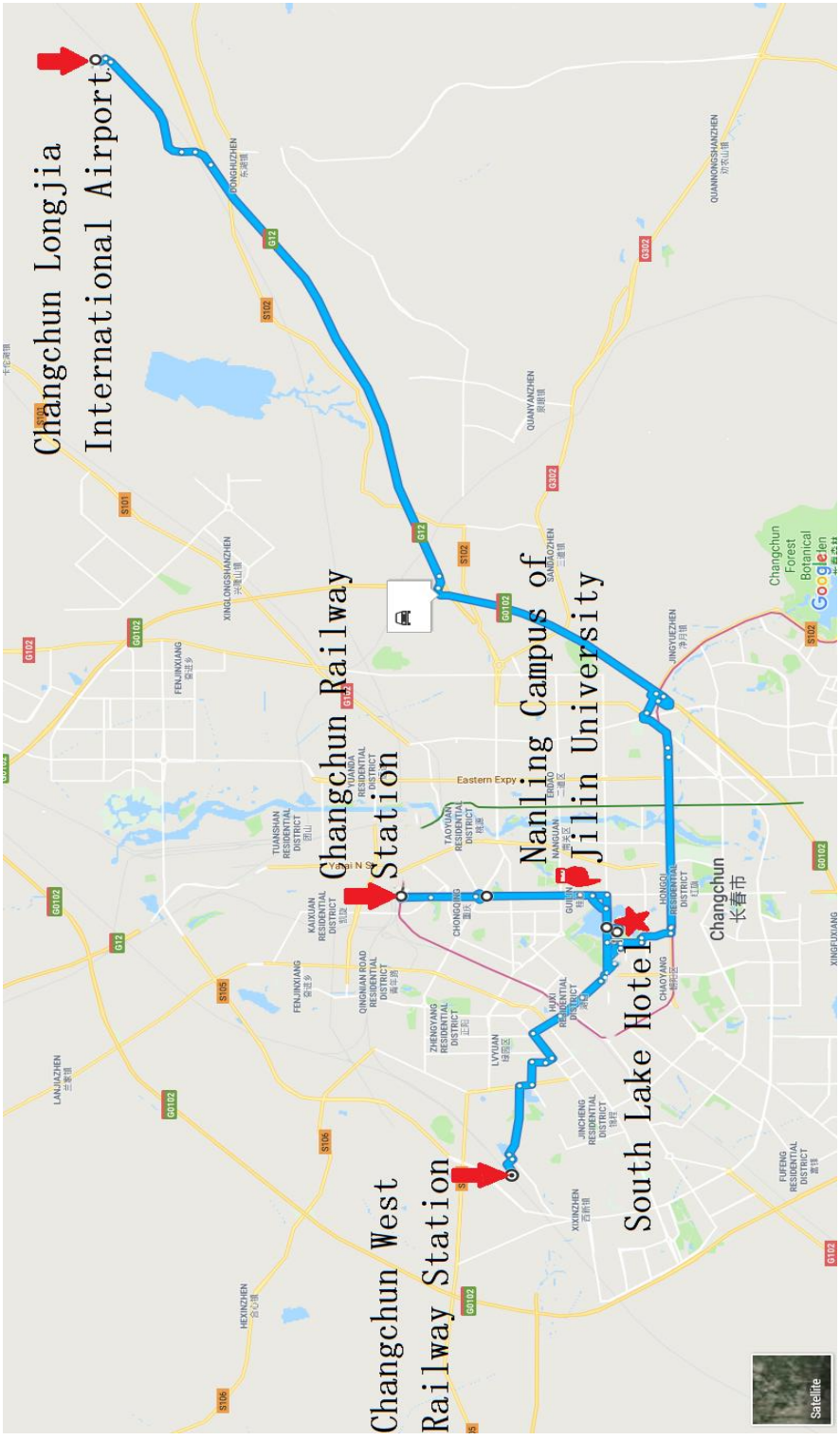
Get on the 55 bus (to Gongnong Road) at Changchun west Railway Station → Get off the bus at Yingchun Road Station → Walk 128 meters and take 252 Bus at Chuncheng Road Station → Get off the bus at South Lake Hotel Station → Walk 559 meters to South Lake Hotel.

Fare: 2 RMB

Or

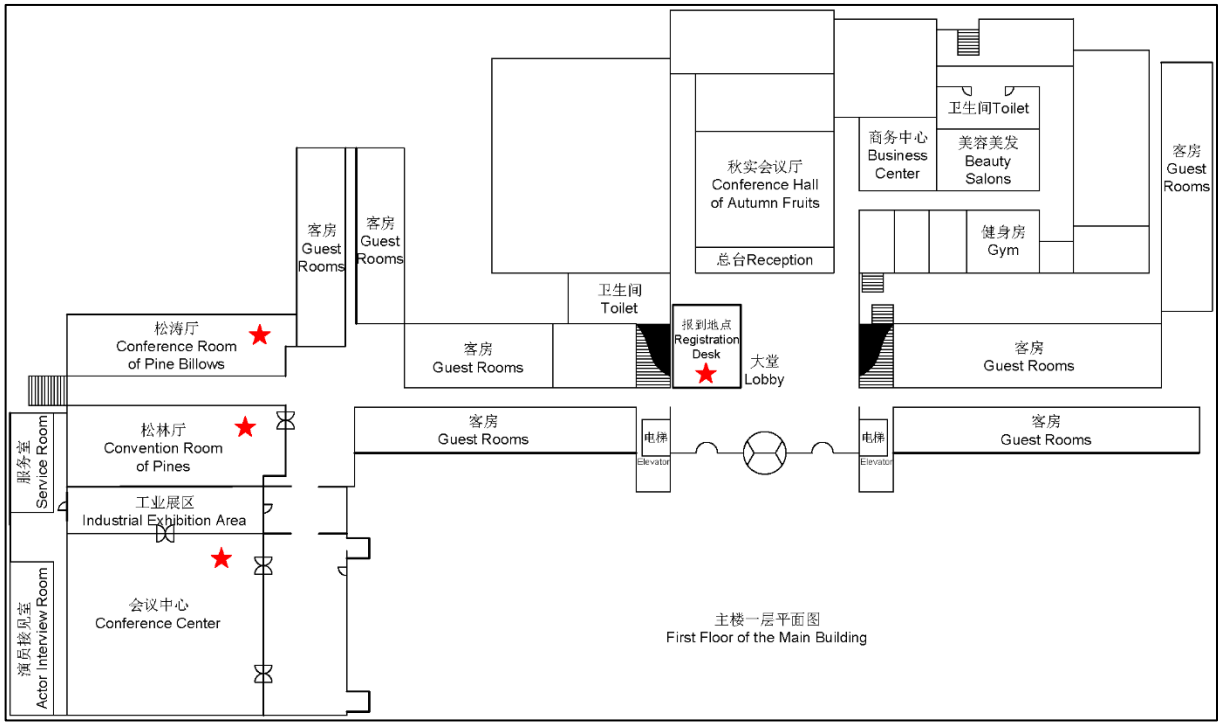
Get on the 159 bus (to Baihui Street) at Changchun west Railway Station → Get off the bus at Chuncheng Road Station → Take 252 Bus at Chuncheng Road Station →Get off the bus at South Lake Hotel Station→ Walk 559 meters to South Lake Hotel.

Fare: 2 RMB

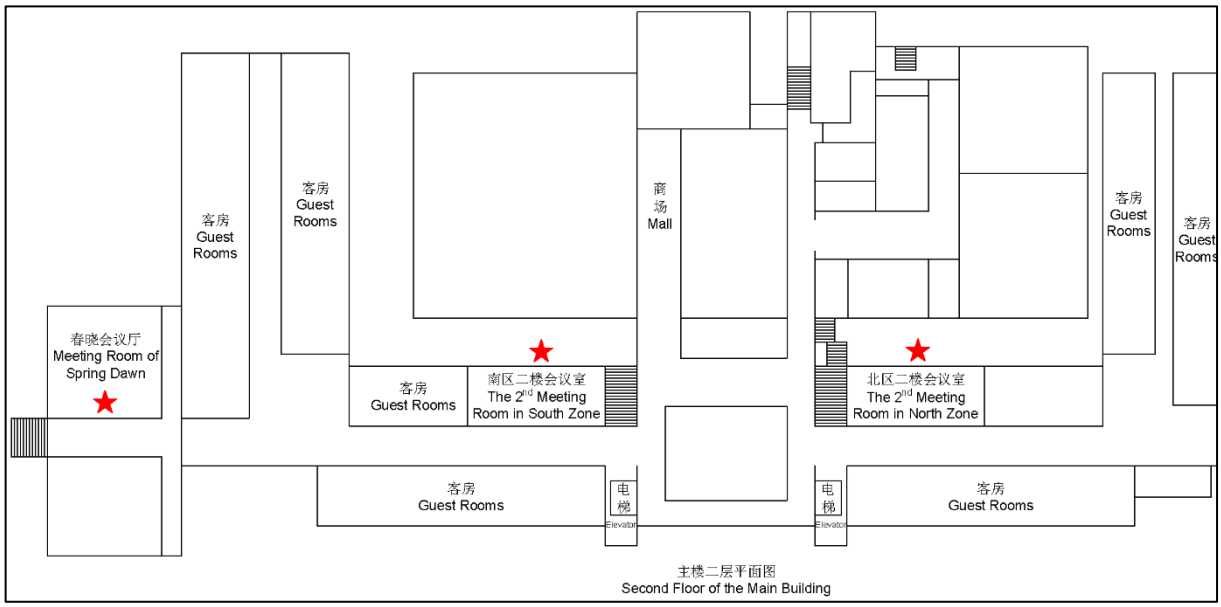


Location of the venue for E-CoSM 2018

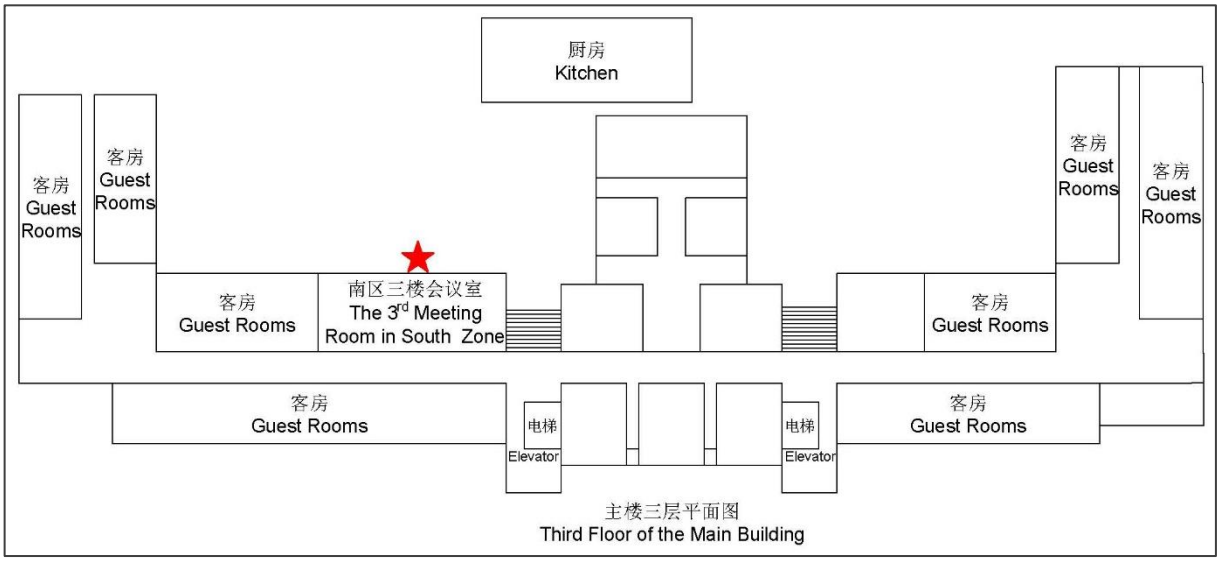
Conference Floor Plan



First Floor of Main Building



Second Floor of Main Building



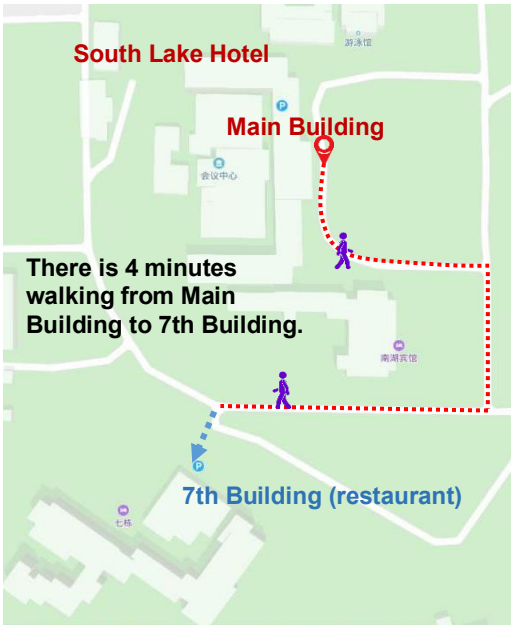
Third Floor of Main Building

Social Events

Welcome Reception

Time: **Sept. 19, 19:00-20:30 (Wed.)**

Venue: **First floor restaurant in the 7th Building, South Lake Hotel**



All conference delegates are warmly invited to attend the welcome reception on Wednesday, 19th September. The reception is a perfect introduction to the conference. It provides a great opportunity for you to meet old fellows and new friends.

Banquet (Ticketed)

Time: **Sept. 21, 18:30 (Fri.)**

Venue: **First floor restaurant, Changchun Celebrity Hotel**

Before the banquet, you will enjoy a mini indoor concert—String Quartet. The String Quartet is a chamber music form composed of four stringed instruments. Consisting of two violins, a viola and a cello, it is the main and most popular chamber music type at present. When light and slender violin, sweet and mellow viola, and vigorous and deep cello are combined together, the second violin is used to double the richness of the high range in terms of melody, level and strength. The four instruments reconcile each other with a balanced, full and perfect sound.

Mini Concert Tracks :

G Major Strings Serenade K525
La La Land Medley
Always with Me
Canon
Acacia River
Merry Widow Waltz

Location of Changchun Celebrity Hotel

Farewell Reception (Buffet)

Time: **Sept. 22, 17:30 (Sat.)**

Venue: **New Business District (NBD) of China FAW R&D Institute**

For those guests who participate in the technical tour and panel discussion, we welcome you to the Farewell Reception at NBD (staff canteen of FAW).

Social Events

Technical Tours

ASCL Lab Tour

Time: Sept. 21, 10:45-12:00 (Fri.)

Bus: Front of the main building, South Lake Hotel

Venue: Nanling Campus of Jilin University

Jilin University

Through more than 70 years of endeavor and development, Jilin University keeps expanding its scale by merging six institutions of higher education successively. At present, Jilin University has become the largest comprehensive university in China, and has been selected as one of the world-class universities, offers all the 13 academic categories, 129 bachelor's, 291 master's, 244 doctor's degree programs and 42 post-doc research stations. The university now has 5 state key laboratories. Also 1 state engineering laboratory, 1 state engineering technology research center, 6 key centers of humanities and social sciences under the Ministry of Education, 10 key laboratories under the Ministry of Education, and 34 international cooperation platforms.

The State Key Laboratory of Automotive Simulation and Control, ASCL

ASCL was ratified to build in 1989, which is one of the first national key laboratories, relies on Mechanical Engineering of Jilin University, a national key discipline. The first driving simulator in China was initiated to develop with a loan of 25million Chinese RMB from the World Bank in 1993. The ADSL driving simulator was successfully developed in 1996. The simulator got through national acceptance and was assessed as "Asian First, World-leading" in December of the same year and then formally opened to domestic and foreign public in 1997. ASCL continuously passed the national evaluation organized by the Ministry of Science and Technology with excellent results in 2003, 2008 and 2013.

The State Key Laboratory of Automotive Simulation and Control (ASCL) focuses on automotive engineering technologies and product development. To take full advantage of complete range of disciplines in Jilin University and further synthesis Power Machinery and Engineering, Transportation and other disciplines based on interdiscipline with Mechatronics, Control and Mechanics etc., the following research areas are finally formed according to the construction orientation and target: 1) Automobile design and theory, 2) High efficient energy saving power and transmission, 3) Advanced automotive structure and material, 4)

Automotive electronic control theory and system technology, 5) Driver-Vehicle-Transport system and Intelligentization.

College of Automotive Engineering

College of Automotive Engineering is an important base for talent cultivation and scientific research for China's automotive industry. Its discipline of Vehicle Engineering is the earliest national key discipline in the automotive field of China. And in recent years, it is regularly ranked amongst the top 3 in national discipline ranking. It based on the college a State Key Laboratory of Automotive Simulation and Control has been established for carrying out leading edge researches targeting to future advanced vehicles.

The college has established several scientific platforms for transportation and power engineering like Automotive Model Design Center, Automotive Test Center, Automotive Performance Laboratory, Energy and Power Engineering Laboratory, and Automotive Parts and Components R&D Center of Jilin Province.

College of Automotive Engineering values undergraduate education, promoting student technology innovation projects through various student interest groups. Among these groups, GSPEED TEAM and CONCEPTION TEAM have made great progress in many national/international competitions under the support of the university and the college, showing the proactive and enterprising spirits of the new generation of Chinese automotive researchers.

FAW R&D Lab Tour

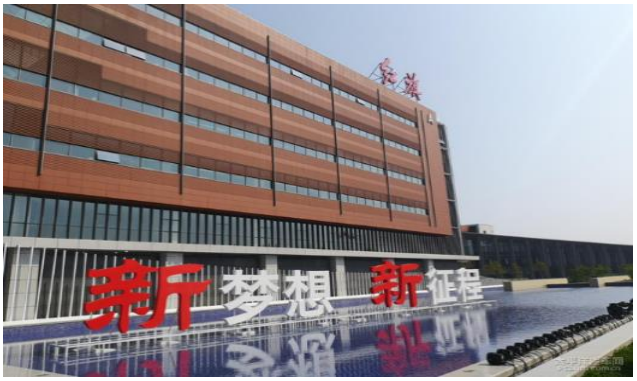
Time: Sept. 22, 13:30-15:00 (Sat.)

Bus: Front of the main building, South Lake Hotel

Venue: New Business District (NBD) of China FAW R&D Institute

FAW (First Automotive Works) is the first auto OEM in China. The first Chinese own made truck JieFang and first luxury car were all born in FAW. FAW exported its first trucks to a customer in Jordan in 1957. Since 1953, FAW has grown over 60 years to become a large automobile enterprise group which can produce and sell 3 million vehicles annually. FAW established and promoted the development of Chinese automobile industry. The company's first medium duty truck, the model JieFang CA10, immediately became a daily sight to people throughout China and a symbol of industrial pride to the country. Hongqi luxury limousine was approved for exclusive use by select government officials and dignitaries.

The R&D Institute is the main part of China FAW Co., Ltd. It is in the leading position in the field of forward-looking technology, engineering design, performance simulation and trial-production test in China. It is also responsible for state key laboratory of Automobile Vibration, Noise and Safety Control Technology, academician workstations and other national research platforms. The Research and Development Institute has 15 departments and 1667 people, mainly responsible for the Product development of Red Flag brand, assembly and platform development of Pentium brand, and responsible for the research and development system construction of the passenger car.



The tour includes:

1. New Energy Development (3 pure electric platforms with independent intellectual property rights)
   - New Energy Development Lab
   - EE Development Lab
   - ICV Car Show
2. ICV Development

Plenary Lectures

Plenary Lecture 1

Time: Sept. 20, 08:45-09:45 (Thu.)

Internal Combustion Engine Today and Tomorrow in China

Jun Li

Tsinghua University, China

Venue : Conference Center **Chair: Hong Chen**

Abstract: Today, the development of internal combustion engine industry in China is facing severe challenges from energy, environment and international competition. Diesel engines emit more carbon dioxide and pollutants than gasoline engines. Heavy-duty diesel engines for application of highway logistics represent the most advanced technology level in power sources of commercial, marine and industrial machinery. How heavy-duty diesel engines confront the challenges of regulations, markets, customers and new energy resources, as well as electromotive technology will directly affect the future of diesel engine industry. By enhancing internal efficiencies add-on waste heat recovery technology, diesel and natural gas engines will achieve BTE 50% to 55% on basis of emitting nearly zero emissions. Combining with compound power technologies, BTE will be further updated to 60%. In highway logistics heavy-duty diesel engines will continue to play an important role as a high-efficiency, clean and intelligent power source in the next 10-20 years.

Dr. Jun Li is now professor of Tsinghua University, Academician of Chinese Academy of Engineering. Dr. Jun Li, a graduate with PhD majored in internal combustion engine of Jilin University of Technology (Formerly Jilin University of Technology) in 1989. He joined Changchun Automobile Research Institute of China FAW Group Corporation shortly after his graduation. Since 2000 he had been the Vice Chief Engineer of China FAW R&D Center, President of FAW R&D Center, Vice Chief Engineer of China FAW, Chief Engineer of China FAW. In March 2018 He joined Tsinghua University, became a professor and PhD student tutor at the department of Automotive Engineering until now.

Academician Li had been leading research and product development, science and technology innovation for a state owned enterprise of automobile, set up leading self reliance R&D system and capacity, accomplished multi product R&D upgrade projects, as well as research projects, such as state 863, 973 programs and important equipment and type R&D projects. In the area of powertrain of automotive he led many projects, such as R&D project of heavy duty diesel engines, turbo charged direct injection gasoline series engines, heavy duty trucks, off road vehicles, and RedFlag limousines, he also invented high pressure injection system with dual rail and variable injection rate, urea pneumatic injection system, FAW diesel injection system for mass production, filled the gap for diesel engine in China. In the area of new energy vehicle R&D, Dr. Li invented strong powertrain architecture with coupling of motor, engine and transmission. He led a team to research and develop strong hybrid powertrain and plug in hybrid powertrain for both cars and buses, in the research area of intelligent and connected vehicle, he proposed technology strategies and technology roadmaps for FAW Zhi Tu, he also accomplished predevelopment for prototype vehicle of RedFlag level 3 and Smart Vehicle for Smart City (SVSC). He was awarded many honorable awards, including the first and the second prize once respectively of the National Science and Technology Progress Award, the second prize of State Technological Invention Award, three times for Special Award of Science and Technology Progress of the Chinese automotive industry, twice for first prize of this award. First prize of National Machinery Science and Technology Progress twice, second prize once, also once won the first prize of Provincial level, he also won the Technology Innovation Prize of the Ho leung Ho lee Foundation in 2012, Dr. Li holds 9 patents and has published 98 papers and one book.

Plenary Lecture 2

Time: Sept. 20, 09:45-10:45 (Thu.)

Actuator and State Constraints in Automotive Engines and Powertrain Systems: What Do We Do About Them?

Ilya V. Kolmanovsky

The University of Michigan, MI, USA

Venue: Conference Center **Chair: Luigi del Re**

Abstract: The presentation will give examples of constraints in engines and powertrain systems, and discuss approaches for handling them through control. Specific emphasis will be on opportunities to systematically implement constraint handling/limit protection capabilities through model predictive control and add-on schemes such as reference governor. Examples of control with constraint handling in turbocharged direct injection gasoline engines and in diesel engines will be given. Free piston engines will also be discussed for which it will be argued that constraint handling algorithms are an enabling technology. Model predictive control solutions for continuously variable transmissions, soft constraint handling in hybrid powertrain systems with small energy storage, and the rollover protection at a vehicle dynamics level will also be considered. The talk will end with perspectives on challenges and opportunities in handling constraints in engine and powertrain control applications.

Dr. Ilya Kolmanovsky has received his M.S. and Ph.D. degrees in aerospace engineering, and the M.A. degree in mathematics from the University of Michigan, Ann Arbor, in 1993 and 1995, respectively. He is presently a full professor at the department of aerospace engineering at the University of Michigan, with research interests in control theory for systems with state and control constraints, and in control applications to automotive and aerospace systems including control and energy management in propulsion systems. Before joining the University of Michigan as a faculty, Dr. Kolmanovsky has been with Ford Research and Advanced Engineering in Dearborn, Michigan, for close to 15 years, where the focus of his research has been on advanced control of engines and powertrain systems to improve their energy efficiency, emissions and performance. Dr. Kolmanovsky is a Fellow of IEEE, a past recipient of the Donald P. Eckman Award of American Automatic Control Council, of two IEEE Transactions on Control Systems Technology Outstanding Paper Awards, and of several awards of Ford Research and Advanced Engineering. He is named as an inventor on 97 United States patents.

With the continuing trends towards growing complexity, downsizing and improved performance, constraint handling and limit protection functions are becoming increasingly important to enable automotive engines and powertrain systems to operate safely at the “limits”. Constraints reflect actuator range and rate limits as well as safety requirements (e.g., speed, torque, pressures, temperatures, flows, etc. should not exceed safe values).

Plenary Lecture 3

Time: Sept. 20, 11:00-12:00 (Thu.)

The Intelligent Powertrain: Model-Predictive Control Based on Vehicle-To-X Communication

Jakob Andert

RWTH Aachen University, Germany

Venue: Conference Center **Chair: Per Tunestål**

Abstract: Modern vehicles are getting more and more connected and autonomous. Until today, the combustion engine control is mainly based on the actual boundaries and the current driver torque demand. A significant improvement of fuel efficiency and emissions can be achieved by connecting the domains of combustion control and vehicle-to-X (V2X) communication. This talk will show the potential of using novel sensors and information sources for predictive combustion control algorithms. It focusses on two sides of the control problem: Firstly, the prediction of the upcoming vehicle speed trajectory depending on complex traffic scenarios is investigated. Secondly, different approaches to utilize the prediction for an improved operation of the combustion engine are presented. Validation is done by simulation, test bench and vehicle measurement.

Jakob Andert is Junior Professor with mechatronic system for combustion engines at RWTH Aachen University, Germany. He received his Ph.D. degree in mechanical engineering from RWTH in 2012. He joined the automotive engineering company FEV in 2011 as a project manager for hybrid and electrified powertrains. He was responsible for various development projects for international OEM and Tier 1, and a wide range from prototype vehicles to series production software development. He joined RWTH Aachen University as Junior Professor with mechatronic systems for combustion engines in 2014. His research interests include realtime-cosimulation, closed-loop HiL testing, 48V powernet development and fast FPGA based combustion control. His laboratory consists of test benches for relevant components of the hybrid powertrain like electric machines, 48V powernets, transient combustion engines benches for passenger cars and heavy duty applications and HV batteries.

Plenary Lecture 4

Time: Sept. 21, 08:30-09:30 (Fri.)

Research Progress of NEV Powertrain and Controls -----Modeling and Control of Automotive Battery and Fuel Cell Systems

Minggao Ouyang

Tsinghua University, China

Venue: Conference Center **Chair: Carlos Guardiola**

Abstract: Firstly, the background of NEV development in China will be introduced. Research progress of NEV powertrain systems in Tsinghua University will be summarized. Then, study on reduced order modeling and state estimation of PEM fuel cells will be presented, including the review of current fuel cell models and new reduced order modeling methodology as well as model-based state estimation. At last, research on simplified P2D model of lithium-ion battery and model-based fast charging control algorithm will be reported.

Prof. Minggao Ouyang graduated from the Technical University of Denmark with a PhD degree in Engineering in 1993. He is currently vice chairman of the Academic Committee of Tsinghua University, director of the State Key Laboratory of Automotive Safety and Energy, Changjiang Distinguished Professor on Automotive Engineering.

Professor Ouyang has long been engaged in research on the advanced vehicle powertrain: systems, models and controls (IC engine and hybrid systems, Lithium-ion battery systems, PEM fuel cell systems). He has presided over many national and international scientific and technological projects, serving as leader of the Panel for Chinese National R&D Program of New Energy Vehicles (2007-), and Chinese Chief Scientist of China-US Electric Vehicle Research Program (2010-). He has been authorized 65 invention patents and has published more than 300 papers on core journals with over 6000 citations (over 150 in SCI-indexed journals, with more than 3000 citations). In addition, he has won the Second-class Prize in the National Technology Invention Award in 2007 and 2010, First-class Prize in the China Automotive Technology Invention Award in 2016, the Prize for Scientific and Technological Achievements from the Ho Leung Ho Lee Foundation in 2008 and the Technical Achievement Award from IPHE in 2010.

Plenary Lecture 5

Time: Sept. 21, 09:30-10:30 (Fri.)

Hitachi Automotive R&D Activity Towards the Era of IoT

Shirou Yamaoka

Hitachi Ltd. Research & Development Group, Japan

Venue: Conference Center **Chair: Hui Xie**

Abstract: The social issues like rapid population growth and air pollution in merging countries, and the market trends like rapid growth of IoT are making the automotive industry place considerable emphasis on the development of EVs and autonomous driving vehicles. HITACHI group is now enhancing the automotive products / system R&D based on such circumstances. The related R&D roadmap and current activity are shown in this presentation.

Dr. Shiro Yamaoka has received his master's degree in mechanical engineering from Keio University in 1999, and entered R&D group in Hitachi Ltd. in 1999. He has been mainly contributing the technology evolution in the field of automotive powertrain area. He started his career with development of advanced engine control systems and new components, addressing gasoline fueled HCCI combustion (1999-2008). He received JSAE award at 2006 regarding the technology presence of gasoline HCCI combustion control, and he was identified as JSAE professional engineer in the field of ICE research. Also his Ph.D. degree was received from Doshisha University in 2016. In addition, he worked at Hitachi Europe GmbH in Munich (2009) as a resident researcher, and started the collaboration research with TU Munich for new combustion concept in gasoline direct injection engine system. After coming back to Hitachi Ltd. in Japan, his working scope was expanded to the control system not only for engine powertrain but for electric vehicles and autonomous driving vehicles (2010-2017). He is currently a department manager in system control architecture research, aiming at realizing safety and sustainable mobility society based on advanced control architecture as the core technology.

Plenary Lecture 6

Time: Sept. 22, 08:15-09:15 (Sat.)

ECMS - from HEV Control Back to Engine Control

Christopher H. Onder
ETH Zurich, Switzerland

Venue: Conference Center **Chair: Tielong Shen**

Abstract: Equivalent consumption minimization strategy is often used for the energy management of hybrid-electric vehicles. It is straightforward understandable and can be easily implemented in an engine control unit. Setting up the optimal control problem and deriving the Hamiltonian show that the equivalence factor can be interpreted as a Lagrangian multiplier. For certain cases the derivative of the Lagragian multiplier can be assumed to be zero, thus the equivalence factor is constant and optimality can be guaranteed. Applying a simple controller, a charge sustaining controller can be found easily.

The same methodology can be applied for the case of engine-out emission control of a combustion engine vehicle. A Lagragian multiplier is defined for each constrained emission component. The derived control strategy balances fuel consumption against legislated emission components if an assumption is made for the average conversion efficiency of the exhaust aftertreatment system. If the derived strategy is stored as a function of the weighting factors, the engine can be operated to achieved different emissions levels according to the legislation without the need of a new calibration. The application of this methodology for diesel engine calibration will be discussed.

Finally, the control of a Formula 1 race car is considered. Again, using Pontryagins Minimum Principle, the complex hybrid powertrain of such a vehicle can be controlled according to the FIA rules achieving minimum laptime.

Christopher H. Onder is professor at the Institute for Dynamic Systems and Control in the Department of Mechanical Engineering and Process Control of ETH Zurich. He heads the Engine Systems Laboratory and holds a diploma and a doctoral degree in Mechanical Engineering from ETH Zurich. He is the author and co-author of numerous articles and a book on modeling and control of engine systems. The list of his awards includes the BMW scientific award, the ETH medal, the Vincent Bendix award, the Crompton Lanchester medal, and the Arch T. Colwell award. Additionally he received several times the Watt d'Or, the energy efficiency price of the department of energy of Switzerland, for his projects. His research focuses on engine system modeling, control and optimization with an emphasis on experimental validation and industrial cooperation.

Academic-industrial Panel Discussion

Time: Sept. 22, 15:00-17:00 (Sat.)

Title：Future Technology Challenge for Sustainable Transportations

Venue: New Business District (NBD) of China FAW R&D Institute **Chair：Gianfranco Rizzo**

Gianfranco Rizzo, University of Salerno

Born in Naples, 1952. Received in 1975 a laurea degree "cum laude" in Mechanical Engineering at University of Naples. He worked at FIAT, at Research National Council of Italy, at University of Naples and at University of Salerno, where he is Full Professor in Mechanical Engineering.
Chair of the Mechanical and Management Engineering Teaching Council. CEO and founder of the spin-off company eproinn. Past Chair of the IFAC TC “Automotive Control” (2008-2014). Associate Editor of Control Engineering Practice. Author of over 150 papers on: modeling and control of automotive engines, hybrid and solar vehicles, renewable energy, optimal management of Bio-Economic systems. Leader and partner of European projects funded by European Committee, industry and public institutions. Member of numerous committees. Recipient of numerous awards. Best Paper Award at AVEC04. Co-Author of a patent on converting conventional cars into Hybrid Solar Vehicles. Accordeonist and founder of the Jazz Orchestra of the University of Salerno.

Special Guests:

Masato Ehara, TOYOTA

Masato Ehara receives his master degree from Kyoto University, Japan, at 1999. He has been working for Toyota since 1999 and his main responsibility has been establishing efficient development process for internal combustion engine control system and utilizing model based calibration. Now he is a project manager and works for further development efficiency improvement introducing model based control technology and machine learning.

Ting He, Dongfeng Motor Technology Center (DFM)

Ting He is a Senior Chief Engineer at Dongfeng Motor Technology Center responsible for the development and deployment of fuel cell vehicles. He has 25 year post-graduate experience at Max-Planck-Institute as an electrochemist, Honda, Phillips 66 and Idaho National Laboratory, led cross-functional, multi-national teams, large research, development organizations, and demonstrated a record of technical accomplishment in fuel cells, photovoltaics, low-carbon hydrogen and clean energy manufacturing. He is the inventor and author of more than 140 patents and referred journal articles. His research interests include the application of advanced materials, electrochemistry, nanotechnology in clean energy systems, transportation science and advanced manufacturing.

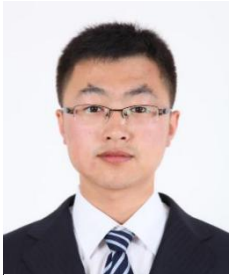
Bian Ning, Dongfeng Motor Technology Center (DFM)

Dr. Bian Ning, Dongfeng Motor Group Co., Ltd.. Director of Intelligent Networking Department of Technology Center, researcher-level senior engineer, engaged in intelligent network technology research and development and application. Dr. Bianning has been working in the automotive industry for the automotive safety and electronics technology since 2005. In particular, the development and mass production applications of the most advanced high-tech technologies, such as autonomous driving technology, integrated chassis control, integrated active and passive safety technologies, accumulate a wealth of core technologies and work results. 5 years ago, he returned to the domestic mainframe factory technology center. Currently, he is mainly responsible for intelligent network (smart driving & advanced assisted driving system), chassis and chassis control, as well as vehicle safety performance, vehicle function development and application.

Yu Wang, First Automotive Works (FAW)

He received the B.E. and Ph.D. degrees in automotive engineering from Jilin University, Jilin, China, in 2009 and 2016, respectively. He is currently working for China FAW Group and engaged in software development of chassis control. His active research interests include intelligent vehicles, vehicle dynamics and control.

Jiwei Wen, First Automotive Works (FAW)



Born in Changchun, 1986. Received a bachelor's degree from Jilin University in 2010. Works at FAW, at E&E Development Department. Group leader of Functional safety. Engaged in automatic transmission control system development, vehicle EE architecture development.

Carlos Guardiola, Universitat de València

Carlos Guardiola received the MS in Mechanical Engineering from the Universitat Politècnica de València (Spain) in 2000, and was honored with the First National Award by the Spanish Education Ministry. He received the PhD degree in 2005 at the same university, and he develops his research activity in the CMT-Motores Térmicos institute of the same university, where he serves now as professor. He leads research on control and diagnosis of internal combustion engines, and has been co-author of more than 100 scientific works, including books, patents, journals and conference papers. He serves as Vice-Chair on Industry of the Technical Committee on Automotive Control of the International Federation of Automatic Control, and he is a member of the Editorial Board of the "Proc. of the Inst. of Mech. Eng., Part D: Journal of Automobile Engineering" and of "Springer Tracts in Mechanical Engineering". He is a recipient of the 2014 Ralph R Teetor Educational Award, by SAE International, and of the 2017 Betancourt y Molina Medal, by the Royal Engineering Academy of Spain.

Ilya Kolmanovsky, University of Michigan

Dr. Ilya Kolmanovsky has received his M.S. and Ph.D. degrees in aerospace engineering, and the M.A. degree in mathematics from the University of Michigan, Ann Arbor, in 1993 and 1995, respectively. He is presently a full professor in the department of aerospace engineering at the University of Michigan, with research interests in control theory for systems with state and control constraints, and in control applications to automotive and aerospace systems including control and energy management in propulsion systems. Before joining the University of Michigan as a faculty, Dr. Kolmanovsky has been with Ford Research and Advanced Engineering in Dearborn, Michigan, for close to 15 years, where the focus of his research has been on advanced control of engines and powertrain systems to improve their energy efficiency, emissions and performance. Dr. Kolmanovsky is a Fellow of IEEE, a past recipient of the Donald P. Eckman Award of American Automatic Control Council, of two IEEE Transactions on Control Systems Technology Outstanding Paper Awards, and of several awards of Ford Research and Advanced Engineering. He is named as an inventor on 97 United States patents.

Lars Eriksson, Linköpings universitet

Lars Eriksson received the M.Sc. degree in Electrical Engineering 1995 and the Ph.D. in Vehicular Systems, 1999, both from Linköping University. His main research interests are modeling, simulation and control of vehicle propulsion system where he has a special interest in issues related internal combustion engines and vehicle powertrains. The following list topics describe the research areas that Lars Eriksson has a high interest in: Ion sensing, zero-dimensional in-cylinder pressure models, calculation of chemical equilibrium, modeling and control of turbocharged SI and DI engines, turbocharger modeling.

Per Tunestål, Lund University

Per Tunestål received his PhD in Mechanical Engineering at the University of California, Berkeley in 2000. He presently holds a position as professor at Lund University where he is in charge of the engine control activities. Per Tunestål also serves as director of The KCFP Engine Research Center, a consortium financed by The Swedish Energy Agency, Lund University and 14 member companies world-wide. Special interests are engine control based on in-cylinder measurements and cylinder-pressure based parameter estimation. Per Tunestål holds more than 100 scientific publications within the combustion engine field and he has served as chairman of the Control and Calibration committee within the Society of Automotive Engineers.

Hong Chen, Jilin University

Hong Chen received the B.S. and M.S. degree from in process control from the Zhejiang University, China, in 1983 and 1986, respectively, and the Ph.D. degree from the University of Stuttgart, Stuttgart, Germany, in 1997. She joined Jilin University of Technology, Changchun, China, in 1986. From 1993 to 1997, she was a “Wissenschaftlicher Mitarbeiter” at the Institut für Systemdynamik und Regelungstechnik, University of Stuttgart. She became an Associate Professor in 1998 and has been a Professor since 1999. Currently, she serves as Tang Aoqing Professor and as the director of the State Key Laboratory of Automotive Simulation and Control. She was awarded the Distinguished Young Scholars of the National Science Fund China in 2007 for her contributions in model predictive control. Her current research interests include model predictive control, optimal and robust control, and nonlinear control and applications in mechatronic systems focusing on automotive systems.

Pre-conference Workshops

Workshop I

Time: Sept. 19, 08:30-11:50 (Wed.)

Venue: 1st Floor Reporting Room, Bionics Building, Nanling Campus, Jilin University

Speaker：Rui Xiong, Beijing Institute of Technology

Title：High-accuracy modeling, state estimation and application of lithium-ion batteries

Abstract: Batteries and their management are a technical bottleneck for electric vehicles. Battery state estimation, which is involved in energy management, cycling life, usage cost and safety, has theoretical meanings and application values. However, the battery has strongly time-variable and nonlinear characteristics, which are further affected by random factors such as working conditions and environment in electric vehicles, resulting great challenges for the accurate state estimation and energy management in real-time. This speech, which will conduct a discussion on issues including mathematically modeling with high accuracy, joint estimation of SOC/SOH/SOP on multi-time scales and its coupling with the model structure and performance, and the on-line application of algorithms, has strong scientific significance and practical engineering values.

Rui Xiong received the M.Sc. degree in automotive engineering and the Ph.D. degree in mechanical engineering from Beijing Institute of Technology, Beijing, China, in 2010 and 2014, respectively. Since 2014, he has been an Associate Professor in the Department of Vehicle Engineering, Beijing Institute of Technology, Beijing, China. Since 2017, he has been an Adjunct Professor in the Faculty of Science, Engineering and Technology, Swinburne University of Technology, Melbourne, Vic., Australia. He has conducted extensive research and authored more than 100 peer-reviewed articles. He holds ten patents. His research interests mainly include electrical/hybrid vehicles, energy storage, and battery management system. Dr. Xiong received the first prize of Chinese Automobile Industry Science and Technology Progress Award in October 2015 and the second prize of National Defense Technology Invention Award in December 2016. He received the 2018 Best Vehicular Electronics Paper Award recognizing the best paper relating to Vehicular Electronics published in the IEEE Transactions on Vehicular Technology during the past 5 years, he also received Best Paper Awards from the Energies and several international conferences. He is serving as a member of the Automation Society Vehicle Control and Intelligence Committee, Associate Editors of IEEE Access and SAE International Journal of Alternative Powertrains, Editorial Board of the Applied Energy, Energies, Sustainability and Batteries, and Guest editor of the Journal of Cleaner Production. He was the conference chair of the 2017 International Symposium on Electric Vehicles held in Stockholm (ISEV2017), Sweden.

Speaker：Bin Duan, Shandong University

Title：A new generation system for battery intelligent test and evaluation

Abstract: The power battery is the heart of EV, performance of the battery test system is crucial to the accuracy and authenticity of the data obtained, which is the cornerstone of battery evaluation. Based on the analysis of related products and technologies at home and abroad, a new generation intelligent test and evaluation system is proposed and its related technical problems have been solved. The third party and experimental results prove that the system can realize intelligent

test and evaluation of power battery. The power battery is the heart of EV. Performance of the battery test system is crucial to the accuracy and authenticity of the data obtained, which is the cornerstone of battery evaluation. Based on the analysis of related products and technologies at home and abroad, a new generation intelligent test and evaluation system is proposed and its related technical problems have been solved. The third party and experimental results prove that the system can realize intelligent test and evaluation of power battery.

Bin Duan, Member of Technical Committee on Vehicle Control and Intelligence, IEEE Member, Associate Professor, Deputy Director of the Automatic Control Institute, and Young Future Scholar of Shandong University. Research interests include advanced control theory methods and power electronics technology in the field of EV power batteries, new energy and so on. Participated or hosted projects include the National Major Scientific Research Instrument Program, Key Program of China Auto Industry Innovation Development Joint Foundation, National Key R&D Program, National Natural Science Foundation, Key R&D Program of Shandong Province (Major Key Technology) and so on. He was awarded several Prizes for Science and Technology Progress (STP) and Education, such as the Second Prize of National STP (seventh), First Prize of Shandong STP (fourth), and the Second Prize of National Teaching Achievement (third), two First Prizes of Shandong Teaching Achievement (third, second), and Special Prize of CAA Higher Education and Teaching Achievement (second).

Speaker：Xiaoxiang Na, Cambridge University

Title：An android application for road freight vehicle in service monitoring

Abstract: An Android app for in-service logging of the operation data of road freight vehicles was developed at the Centre of Sustainable Road Freight (SRF) at the University of Cambridge. It was thus named “SRF Logger”. The “SRF Logger” app generally serves two functions: 1) logging vehicle operation data in-service, and 2) transmitting data logged to a remote server in real-time. Key features of “SRF Logger” are described, and example data logged by “SRF Logger” are presented. Potential applications of “SRF Logger” to driving cycle measurement, engine fuel map reconstruction and vehicle parameter estimation are discussed.

Xiaoxiang Na received the B.S. and M.S. degrees in Automotive Engineering from the College of Automotive Engineering, Jilin University, China, in 2007 and 2009, respectively, and the Ph.D. degree in driver-vehicle dynamics from the Department of Engineering, University of Cambridge, U.K., in 2014. He started his career as a Research Assistant with the Centre for Sustainable Road Freight at the University of Cambridge, U.K. in 2014, where he is currently a Research Associate. He is currently the vice-secretary of the international Parallel Driving Alliance (iPDA), and a member of the Technical Committee on Parallel Intelligence at the Chinese Association of Automation. His research interest includes driver-vehicle dynamics, decision-making in intelligent vehicle systems and driver control of vehicle energy consumption. Recently he has been working on development of intelligent telematics for in-service monitoring of road freight operation.

Workshop Ⅱ

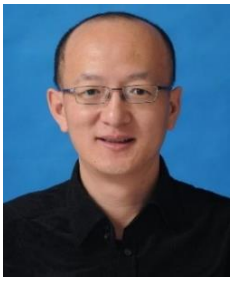
Time: Sept. 19, 08:30-11:50 (Wed.)

Venue: Conference Room 209, Bionics Building, Nanling Campus, Jilin University

Speaker：Shuyou Yu, Jilin University

Title：Stability and inherent robustness of discrete time nonlinear model predictive control

Abstract: The main idea behind model predictive control (MPC) is to solve an optimization problem online. On one hand, in reality, model/plant mismatches, exogenous disturbances, numerical errors and state measurement errors are present. On the other hand, model predictive control provides a feedback only at specific sampling instant and the system is open-loop controlled between adjacent sampling instants. Therefore, robust analysis and synthesis of MPC are of significantly theoretical and practical importance.



Shuyou Yu received the B.S. and M.S. degrees in Control Science & Engineering at Jilin University, PR China, in 1997 and 2005, respectively, and the Ph.D. degree in Engineering Cybernetics at the University of Stuttgart, Germany, in 2011. From 2010 to 2011, he was a research and teaching assistant at the Institute for Systems Theory and Automatic Control at the University of Stuttgart. In 2012, he joined the faculty of the Department of Control Science & Engineering at Jilin University, PR China, where he is currently a full professor. His main areas of interests are model predictive control, robust control, and applications in mechatronic systems.

Speaker：Fang Xu, Jilin University

Title：Real-time implementation of model predictive control and its applications

Abstract: Owing to the ability to handle multi-variable/multi-objective problems and deal with hard constraints explicitly, model predictive control (MPC) has become an attractive feedback strategy in a broad range of systems, and its application has been extended from process industry systems to fast dynamic systems. MPC requires repeated online solution of a receding horizon optimization problem at every sampling instant. The computation load remains the main challenge for the real-time practical application of MPC especially for fast systems. Moreover, fast systems require the MPC controller for high computational performance, miniaturization and high-level integration on a chip. This talk introduces some recent work on field programmable gate array (FPGA) implementation schemes and its applications in automotive control systems. Based on the FPGA-in-the-loop testbench, simulation and experimental results will be given to demonstrate the efficacy and real-time performance of the MPC-on-FPGA-chip strategy.

Fang Xu received the B.S. degree in automation and the Ph.D. degree in control theory and control engineering from Jilin University, Changchun, China, in 2009 and 2014, respectively. She is currently a Lecturer with the Department of Control Science and Engineering, Jilin University. Her current research interests include model predictive control, optimization methods, and field-programmable gate arrays.

Speaker：Hongyan Guo, Jilin University

Title：An MPC application in path planning, following and driver automation collaboration of an intelligent vehicle

Abstract: With the rapid development of intelligent transportation systems and automobile technology, intelligent vehicles have aroused many researchers' attention due to various potential applications, such as reducing traffic congestion and traffic accidents, etc. Intelligent vehicles are comprehensive applications of multi-discipline knowledge and theories, in which path planning, path following and driver-automation collaboration are the three main components of the software configuration. With the rapid development of online optimization and hardware implementation, model predictive control (MPC) has attracted many focuses on discussing path planning, path following, and driver-automation collaboration issue of intelligent vehicles. In this speech, the development of the path planning, path following and driver-automation collaboration issues using MPC approach and present future concerns and perspectives for intelligent vehicles will be discussed.

Hongyan Guo received the MS in Control Theory and Control Engineering from the University of Science and Technology Liaoning in 2007, and received the Ph.D. degree in 2010 from Jilin University. She joined Jilin University, China, in 2011, where she became an Associate Professor in 2014. In the same year, she was selected as Jilin University funds for Excellent Young Scholars. In 2018, she received Jilin University funds for Distinguished Young Scholars. From 2016.11 to 2017.11, she was a Visiting Scholar with Cranfield University, Cranfield, U.K. Her current research interests include vehicle driving states and parameters estimation, vehicle active safety control, human-automation collaboration, and path planning and following of intelligent vehicles, and have been co-author of more than 50 scientific works, including journal and conference papers. She has applied for 21 items of the national invention patent and 12 items has been authorized. She was awarded first prize in natural science of Jilin Province in 2017 (5/10). In 2015, she received National Natural Science Foundation Youth Fund Project, and severed as a leader of 3 items National Natural Science Foundation subproject. In 2017, she became a committee member of Technical Committee on Vehicle Control and Intelligence, Chinese Association of Automation. In 2018, she joined Group of Women Scholar in Control and became a member. She also severed as a reviewer of many international journals, such as IEEE Trans on Vehicular Technology，IEEE/ASME Trans on Mechatronics, IEEE Trans on Industrial Electronics，IEEE/CAA Journal of Automatica Sinica, etc.

Workshop Ⅲ

Time: Sept. 19, 14:00-16:10 (Wed)

Venue: 1st Floor Reporting Room, Bionics Building, Nanling Campus, Jilin University

Speaker：Carlos Guardiola, Universitat de València

Title：Detection and modeling of knock distribution in SI engines

Abstract: Knock phenomenon may be studied and characterized in the time-frequency domain. From the analysis results, a new knock event definition may be derived, directly comparing the excitation of the cylinder resonance produced by the autoignition of the end gas to that associated with the flame propagation. The new definition permits a more consistent differentiation between knocking and not knocking cycles than the classical approach in the literature, thus allowing the improvement of the knock control strategies. On the other hand, a knock model combining a deterministic knock model

based on the in-cylinder temperature and an exogenous noise disturbing this temperature is presented. The autoignition of the end-gas is modelled by an Arrhenius-like function and the knock probability is estimated by propagating a virtual error probability distribution. Results show that the random nature of knock can be explained by uncertainties at the in-cylinder temperature estimation. The model only has one parameter for calibration and thus can be easily adapted online. In order to reduce the measurement uncertainties associated with the air mass flow sensor, the trapped mass is derived from the in-cylinder pressure resonance, which improves the knock probability estimation and reduces the number of sensors needed for the model.

Carlos Guardiola received the MS in Mechanical Engineering from the Universitat Politècnica de València (Spain) in 2000, and was honored with the First National Award by the Spanish Education Ministry. He received the PhD degree in 2005 at the same university, and he develops his research activity in the CMT-Motores Térmicos institute of the same university, where he serves now as Professor. He leads research on control and diagnosis of internal combustion engines, and has been co-author of more than 100 scientific works, including books, patents and journal and conference papers. He serves as Vice-Chair on Industry of the Technical Committee on Automotive Control of the International Federation of Automatic Control, and he is a member of the Editorial Board of the "Proc. of the Inst. of Mech. Eng., Part D: Journal of Automobile Engineering" and of "Springer Tracts in Mechanical Engineering". He is a recipient of the 2014 Ralph R Teetor Educational Award, by SAE International, and of the 2017 Betancourt y Molina Medal, by the Royal Engineering Academy of Spain.

Speaker：Yui Nishio, Honda Automotive R&D Center

Title：Model-based development and advanced control strategy of powertrains

Abstract: In this talk, the latest activity of Honda all over the world, model-based development of powertrains, and model-based powertrains control as a future control technique will be discussed. It is a challenge to sufficiently validate RDE (Real Driving Emission) performance under all conditions through road tests during vehicle development. A model-based development technology was established to simulate, verify and calibrate the emissions performance of a diesel vehicle. RDE permanence could be accurately predicted by coupling a vehicle driving simulation with an engine simulation that includes an ECU model, combustion model, and exhaust aftertreatment catalyst model. As a future control technique, the receding horizon optimal control is focused much attention in automotive control system applications due to the advantages in dealing with constrained optimization explicitly, multi-cost function, and the feedback structure etc. However, a key issue in conducting receding horizon optimization strategy is the constraint that the actual generated torque has to satisfy the demanded torque by the driver during the predictive period. This talk provides a receding horizon optimal control strategy with driver's demand prediction based on the traffic information in the sense of the learning of probability distribution of the demanded torque.

Yui Nishio received the M.E. degree in mechanical engineering from Waseda University, Japan, in 2009.He is currently an assistant chief engineer of Honda Automotive R&D center, and a Ph. D. student in Sophia university, Japan. He has more than eight years experiences in diesel engine field, where he has addressed model-based air path control, study of control and optimization strategy for diesel hybrid system, model-based calibration methodology and optimization, and advanced research of high efficient engines. His current jobs are development of advanced hybrid powertrain system, and construction of simulation environment for efficient calibration of hybrid system. His research topics in Sophia University are powertrain control with traffic information, model predicted control, and optimization.

Workshop IV

Time: Sept. 19, 14:00-16:10 (Wed)

Venue: Conference Room 209, Bionics Building, Nanling Campus, Jilin University

Speaker：Lars Eriksson, Linköping University

Title：Model-based development - the prosperous life, evolution, & impact of a diesel engine model

Abstract: Control systems have come to play an important role in the performance of modern vehicles with regards to meeting goals on low emissions and fuel consumption. In the development process, new technologies are introduced and the vehicle systems become more complex to enable optimization of the performance. Model based development is seen as a key methodology for handling the complexity and guiding the development and optimization of future complex hybrid electric vehicles. It can help reduce the time to market and thus increase the pace of innovation, but a cornerstone for a high innovation pace is the availability and reusability of models. In this presentation, we will follow the initiation and development of a diesel engine model that has been much used and evolved over the years to become used in a wide range of applications beyond the initial intentions. Starting as a model for a long haulage truck it has been refitted to a passenger car, reused in a diesel electric powertrain in an off-highway application, reused as building blocks for a large marine engine model. It is now the cornerstone in a benchmark model for development of planning strategies in future connected vehicles as well as in a model for studying hybrid vehicles and how the powertrain interacts with the after-treatment system. Much of the success of the model builds on the fact that it is component based, systematically developed and adapted to a real-world engine and that it was released as an open source model that can be downloaded freely and modified. As a key result, it will showcase the importance of control and how model based control can contribute to clean and efficient transports.

Lars Eriksson received the M.S. degree in Electrical Engineering 1995 and the Ph.D. in Vehicular Systems, 1999, both from Linköping University. His main research interests are modeling, simulation and control of vehicle propulsion system where he has a special interest in issues related to internal combustion engines and vehicle powertrains. The following list topics describe the research areas that Lars Eriksson has a high interest in: Ion sensing, Zero-dimensional in-cylinder pressure models, Calculation of chemical equilibrium, Modeling and control of turbocharged SI and DI engines, Turbocharger modeling, Optimal control of complex and hybrid powertrains.

Speaker：Masato Ehara, Toyota

Title：Control technology and development process for evolving powertrain

Abstract: Recently powertrain keeps increasing complexity from a sole simple internal combustion engine to a combination of ICE and electrified power units. Powertrain control has a large effect to performance and cost but required development cost keeps rising, hence, development efficiency improvement is a key issue. Efforts to reduce development cost, especially for calibration process at automotive industry will be presented.

Masato Ehara receives his master degree from Kyoto University, Japan, in 1999. He has been working for Toyota since 1999 and his main responsibility has been establishing efficient development process for internal combustion engine control system utilizing model based calibration. Now he is a project manager and works for further development efficiency improvement introducing model based control technology and machine learning.

Industrial Forums

Time: Sept. 21, 13:00-15:30 (Fri.) Venue : Conference Room of Pine Billows, South Lake Hotel Organizer：Ning Bian, Dongfeng Motor Technology Center	
Time	**Speakers**
13:00-13:25	Fengjun Li, China FAW Group Co., Ltd.
13:25-13:50	Junqiang Shen, Freetech Intelligent Systems Co., Ltd.
13:50-14:15	Manoj Mohamed, ZF Friedrichshafen AG
14:15-14:40	Yong Zhou, Continental AG
14:40-15:05	Gansha Wu, UISEE Technologies Ltd.
15:05-15:30	Ting He, Dongfeng Motor Technology Center
Time: Sept. 21, 15:50-17:35 (Fri.) Venue : Conference Room of Pine Billows, South Lake Hotel Organizer：Jinwu Gao, Jilin University	
Time	**Speakers**
15:50-17:05	Youshu Kang, Cybernet Systems (Shanghai) Co., Ltd.
17:05-17:35	Ken Dunstan, MathWorks, Inc.

Benchmark Challenge on Engine Control

In order to deepen academic research in the field of vehicle control and attract more researchers from relevant areas to strengthen collaboration, E-CoSM 2018 and Technical Committee on Vehicle Control and the Intelligence of CAA officially launch the first issue of the Benchmark Challenge, with the topic of "Rail Pressure Control of Common Rail System for Gasoline Direct Injection Engines". The works of the competition includes program test and presentation displayed in the form of poster. During the posting period, the review team will conduct on-site review and any conference participants can vote for their favored works during the display. The results of the competition will be announced at the Banquet and the conference committee will award the excellent team with certificate and prize.

Time: Sept. 20-Sept. 22, coffee break **Venue: Industrial Exhibition Area (near by the Conference Center)**
Award time: Sept. 21, Banquet **Venue: First floor restaurant, Changchun Celebrity Hotel**

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Program at a Glance

Wednesday, Sept. 19, 2018		
	Workshop I (CVCI 2018)	**Workshop II (CVCI 2018)**
8:30-11:50	1st Floor Reporting Room, Bionics Building, Nanling Campus, Jilin University High-accuracy modeling, state estimation and application of lithium-ion batteries by Rui Xiong A new generation system for battery intelligent test and evaluation by Bin Duan An android application for road freight vehicle in service monitoring by Xiaoxiang Na	No. 209, Bionics Building, Nanling Campus, Jilin University Stability and inherent robustness of discrete time nonlinear model predictive control by Shuyou Yu Real-time implementation of model predictive control and its applications by Fang Xu An MPC application in path planning, following and driver automation collaboration of an intelligent vehicle by Hongyan Guo
	Workshop III (CVCI 2018)	**Workshop IV (CVCI 2018)**
14:00-16:10	1st Floor Reporting Room, Bionics Building, Nanling Campus, Jilin University Detection and modeling of knock distribution in SI engines by Carlos Guardiola Model-based development and advanced control strategy of powertrains by Yui Nishio	No. 209, Bionics Building, Nanling Campus, Jilin University Model-Based Development - The Prosperous Life, Evolution, & Impact of a Diesel Engine Model by Lars Eriksson Control technology and development process for evolving powertrain by Masato Ehara
19:00-20:30	Welcome Reception	

Thursday, Sept. 20, 2018						
8:30-8:45	Opening Address (ThMC) Venue: Conference Center（会议中心）					
8:45-9:45	Plenary Lecture 1 (ThP1P1): Internal Combustion Engine Today and Tomorrow in China by Jun Li Chair: Hong Chen Venue: Conference Center（会议中心）					
9:45-10:45	Plenary Lecture 2 (ThP2P1): Actuator and State Constraints in Automotive Engines and Powertrain Systems: What Do We Do About Them? by Ilya V. Kolmanovsky Chair: Luigi del Re Venue: Conference Center（会议中心）					
10:45-11:00	Coffee Break					
11:00-12:00	Plenary Lecture 3 (ThP3P1): The Intelligent Powertrain: Model-Predictive Control Based on Vehicle-To-X Communication by Jakob Andert Chair: Per Tunestål Venue: Conference Center（会议中心）					
12:00-13:00	Lunch					
13:00-15:00	**Session ThA1** Conference Room of Pine Billows （松涛会议厅） Hybrid and Electric Vehicles I	**Session ThA2** Convention Room of Pines （松林会议厅） Engine and Powertrain Control I	**Session ThA3** The 2nd Meeting Room In South Zone （南区二会议室） Control Strategies for Electronic Machine and Evs	**Session ThA4** Meeting Room of Spring Dawn （春晓会议厅） Closed-loop Combustion Control	**Session ThA5** The 2nd Meeting Room In North Zone （北区二会议室） Nonlinear Intelligent Control of Automobile	**Session ThA6** The 3rd Meeting Room In South Zone （南区三会议室） Applications of Advanced Control Technologies to Engines and Vehicles
15:00-15:20	Coffee Break					
15:20-17:40	**Session ThE1** Conference Room of Pine Billows （松涛会议厅） Hybrid and Electric Vehicles II	**Session ThE2** Convention Room of Pines （松林会议厅） Engine and Powertrain Control II	**Session ThE3** The 2nd Meeting Room In South Zone （南区二会议室） Estimation and Control for Battery	**Session ThE4** Meeting Room of Spring Dawn （春晓会议厅） Practical Combustion Control	**Session ThE5** The 2nd Meeting Room In North Zone （北区二会议室） Driver Assistance and Vehicle Dynamics	**Session ThE6** The 3rd Meeting Room In South Zone （南区三会议室） Engine After-Treatment Control and Diagnosis
18:00-19:30	TC 7.1 Meeting Venue: The 2nd Meeting Room In South Zone（南区二会议室）					

Friday, Sept. 21, 2018						
8:30-9:30	Plenary Lecture 4 (FrP1P): Research Progress of NEV Powertrain and Controls-----Modeling and Control of Automotive Battery and Fuel Cell Systems by Minggao Ouyang Chair: Carlos Guardiola Venue: Conference Center（会议中心）					
9:30-10:30	Plenary Lecture 5 (FrP2P): Hitachi Automotive R&D Activity Towards the Era of IoT by Shirou Yamaoka Chair：Hui Xie Venue: Conference Center（会议中心）					
10:30-10:45	Coffee Break					
10:45-12:00	Lab Tour:State Key Laboratory of Automotive Simulation and Control, Jilin University (FrTT)					
12:00-13:00	Lunch					
13:00-15:20	**Session FrA2** Convention Room of Pines （松林会议厅） Hybrid and Electric Vehicles III	**Session FrA3** The 2nd Meeting Room In South Zone （南区二会议室） Engine and Powertrain Control III	**Session FrA4** Meeting Room of Spring Dawn （春晓会议厅） Electronic Architectures and Control	**Session FrA5** The 2nd Meeting Room In North Zone （北区二会议室） Diesel Engine Combustion and Air-path System Control	**Session FrA6** The 3rd Meeting Room In South Zone （南区三会议室） Vehicle Control	**Industrial Forum I FrA1** 13:00-15:30 Conference Room of Pine Billows （松涛会议厅）
15:20-15:40	Coffee Break					15:30-15:50
15:40-17:40	**Session FrE2** Convention Room of Pines （松林会议厅） HEV Energy Management	**Session FrE3** The 2nd Meeting Room In South Zone （南区二会议室） Predictive Control of Powertrain	**Session FrE4** Meeting Room of Spring Dawn （春晓会议厅） Intelligent Management and Power Electronics Technology	**Session FrE5** The 2nd Meeting Room In North Zone （北区二会议室） Combustion Control	**Session FrE6** The 3rd Meeting Room In South Zone （南区三会议室） Advanced Design and Control for Energy Efficient Powertrain	**Industrial Forum II FrE1** 15:50-17:35 Conference Room of Pine Billows （松涛会议厅）
18:30-21:00	Banquet					

Saturday, Sept. 22, 2018						
8:30-9:30	Plenary Lecture 6 (SaP1P): ECMS - from HEV Control Back to Engine Control by Christopher H. Onder Chair: Tielong Shen Venue: Conference Center（会议中心）					
9:30-9:45	Coffee Break					
9:45-11:45	**Session SaM1** Conference Room of Pine Billows （松涛会议厅） New Energy and Intelligent Vehicle Technology	**Session SaM2** Convention Room of Pines （松林会议厅） Transient Control and Optimization for Engines	**Session SaM3** The 2nd Meeting Room In South Zone （南区二会议室） Cruise, Driving, and Control	**Session SaM4** Meeting Room of Spring Dawn （春晓会议厅） Driveline Control Technologies	**Session SaM5** The 2nd Meeting Room In North Zone （北区二会议室） Autonomous Vehicle and Control	**Session SaM6** The 3rd Meeting Room In South Zone （南区三会议室） Advanced Modeling and Control of Vehicle Ride Dynamics
11:45-13:30	Lunch					
13:30-15:00	Technical Tours to China FAW R&D Institute (Bus departure at Conference Center)					
15:00-17:00	Academic-Industrial Panel Discussion at China FAW R&D Institute (Chaired by Gianfranco Rizzo)					
17:30	Farewell Reception					

Invited Session Regular Session

Book of Abstracts of 5th IFAC Conference on Engine and Powertrain Control, Simulation and Modeling

Technical Program for Thursday September 20, 2018

ThA1 Conference Room of Pine Billows

Hybrid and Electric Vehicles I (Invited session)

Chair: Zhou, Shiying — FAW
Co-Chair: Ma, Yan — Jilin Univ
Organizer: Zhou, Shiying — FAW

13:00-13:20 ThA1.1

Energy Management of Low Voltage Power Supply of Plug-In Hybrid Electric Vehicle (I), pp. 1-6

Zhao, Yongqiang — China First Group Corp
Wang, Yueqiang — China First Group Corp
Song, Haoyuan — China First Group Corp

Under the pressure of energy crisis and environmental pollutions, regulations of automotive emission and energy consumption are becoming more and more stringent. Plug-in Hybrid Electric Vehicle (PHEV), which can solve environmental issues and mileage limitations, becomes the most popular development trend at present. Optimization control of power battery energy contributes greatly to improving vehicle fuel economy and dynamic performance, energy optimization control of vehicle low voltage power supply also has significant influence on vehicle fuel consumption and dynamic performance. In this paper, a Low-Voltage Power Supply Energy Management System (LVPSEMS) is proposed to optimize the energy of low voltage power supply of PHEV. Dynamic management voltage output of DC/DC is conducted and realized based on vehicle states, power battery SOC and low voltage battery status with the purpose of achieving fuel economy and dynamic performance of automobile. The tests in vehicle show that the proposed LVPSEMS and control strategy can effectively improve the pure electric mileage of 1.72% and reduce the electric energy consumption by 4%.

13:20-13:40 ThA1.2

Development of a Engine Start Control for P2 Hybrid Vehicles in Launch Situation (I), pp. 7-10

Ning, Jiakui — China Faw Group Co., Ltd
Zhu, Guiqing — FAW
Qu, Baixue — FAW

Abstract: In this paper, the P2 hybrid system with dual clutch automatic transmission (DCT) is used as the research object, and the process which the vehicle driven by motor alone switch to driven by engine in launch situation is analyzed. Focusing on preventing the wheel driving torque variation caused by motor torque rising instantaneously in the process of engine start, the effective method of let the DCT clutch slip at a desired speed, coordinated control strategy of power source torque to reduce the jerk of the vehicle in different launch situation is proposed. Finally, the strategy is verified through vehicle test, the test results showed that the control strategy proposed in this paper can improve the ride comfort of the vehicle during the driving mode transition process effectively.

13:40-14:00 ThA1.3

Research on Fast Matching Method of Power System Parameters of Parallel Hybrid Electric Vehicles (I), pp. 11-14

Guo, Bin — Jilin Univ
Song, Dafeng — Jilin Univ. State Key Lab. of Automotive Simulation

Aiming at the parameter matching problem of the single-shaft hybrid SUV power system whose engine power has been determined by the manufacturer, a fast matching method for dynamic component parameters based on automobile theory is proposed. The main parameters of BSG motor, ISG motor and power battery are obtained by matching. Then a joint simulation model is established based on Cruise and MATLAB/Simulink simulation software. The results of the joint simulation show that the matched vehicle dynamics meet the design targets and the fuel economy is improved by more than 30%.

14:00-14:20 ThA1.4

Oxygen Excess Ratio Control of PEM Fuel Cell Based on Self-Adaptive Fuzzy PID, pp. 15-20

Zhang, Fan — Jilin Univ. (Campus NanLing)
Yu, Xiaolei — Jilin Univ
Ma, Yan — Jilin Univ
Chen, Hong — Jilin Univ. Campus NanLing

Oxygen excess ratio is closely related to the output efficiency and service life of the proton exchange membrane (PEM) fuel cell system. To simulate dynamic behaviors of air flow, a fourth-order model of PEM fuel cell system is established. Then, a self adaptive fuzzy PID (SFPID) controller is proposed to regulate the oxygen excess ratio on-line through its adaptive characteristic. Under different current disturbances, a comparison of proposed SFPID with several control topologies such as feedforward, PID, and PID plus feedforward (PID-FF) is carried out to validate the advantages of the proposed controller. Moreover, the proposed SFPID controller is applied to track the variable oxygen excess ratio. The simulation results display that the set-point value of oxygen excess ratio can be tracked rapidly and accurately, and verify that the proposed SFPID controller has good dynamic response performance.

14:20-14:40 ThA1.5

Research on Parameters Matching Design Method for Planetary Hybrid Logistics Vehicle, pp. 21-28

Song, Dafeng — Jilin Univ. State Key Lab. of Automotive Simulation
Yu, Fukang — Jilin Univ
Zeng, Xiaohua — Jilin Univ
Yang, Nannan — Jilin Univ. State Key Lab. of Automotive Simulation
Wang, Zhenwei — Jilin Univ

Abstract: This article applies planetary hybrid system to logistics vehicles, and parameter matching of key components for vehicle power source. In the matching of planetary rows, a method based on the optimal solution of the eigenvalues of the transmission system efficiency is used to optimize the selection of eigenvalues. Considering the full use of engine dynamics, the two motors are matched in the case of using the engine's external characteristic strategy, and they are solved under the limit conditions and C-WTVC operating conditions respectively. When energy matching is performed on the super capacitor, the kinematics segmentation is performed on the operating conditions to analyze the energy variation in each segment. Finally, a logistics vehicle model is established in Cruise to simulate the dynamics and economy to prove the reasonable matching method.

14:40-15:00 ThA1.6

Dynamic Simulation of an ICE-ORC Combined System under Various Working Conditions, pp. 29-34

Liu, Tong — Beijing Inst. of Tech
Wang, Enhua — Beijing Inst. of Tech
Meng, Fanxiao — Beijing Inst. of Tech
Zhang, Xu — Beijing Inst. of Tech

In recent years, energy conservation and emission reduction have been the main targets for the industry of internal combustion engine (ICE). The waste heat recovery from ICEs can improve the overall

energy efficiency obviously and reduce fuel consumption greatly. Organic Rankine cycle (ORC) is a promising approach to recover waste heat energy and has been used to harness low-grade heat extensively. In this paper, a simulation model of a combined system of ICE-ORC is built using GT-Suite software. Then, the dynamic performance of the ICE-ORC combined system is studied. The results can provide some meaningful insights for the practical application of ORC system on automotive engines.

ThA2 Convention Room of Pines

Engine and Powertrain Control I (Invited session)

Chair: Yamakita, Masaki — Tokyo Inst. of Tech
Co-Chair: Iwase, Masami — Tokyo Denki Univ
Organizer: Shen, Tielong — Sophia Univ

13:00-13:20 ThA2.1

Decrease of Minimum Injection Fuel Mass on the Basis of the Micro-Sec-Level Production Error Detection (I), pp. 35-40

Aono, Toshihiro — HItachi Ltd.,

In recent papers on signal processing in automotive engine control, we noticed the papers about production deviation detection. To clear recent regulations about automotive emission, multiple injection is required. Fuel injection quantity for multiple injection is so small that injection deviation due to injector production variation becomes a serious problem. Attempts to detect and correct the injector production error have started. Injector production error is detected by identifying the inflection point of solenoid voltage caused by the electromotive force change at injector valve closing. This detection is disturbed by noise from DCDC converter and PWM controller. To overcome the disturbance, we developed a noise robust FIR filter, whose gain drops sharply in noise area, however, this filter requires high calculation performance and suffers from aliasing problem. Moreover, the signal change at injector closing is so slight that the voltage resolution of AD conversion must be high. These problems were cleared by adopting mass-production engine-control micro-computer RH850Ex1. We evaluated the performance of detection of valve closing and confirmed the reduction of minimum fuel injection mass, enabled by the correction of production deviation on the basis of the detection.

13:20-13:40 ThA2.2

A Parallelized Method for Discrete-Time Models with Dependence on Calculation Order (I), pp. 41-45

Sata, Kota — TOYOTA MOTOR Corp
Matsunaga, Akio — Toyota Motor Corp
Ohata, Akira — Sophia Univ
Azuma, Shun-ichi — Nagoya Univ

The advancement of the powertrain control increases the amount of computation. The mass production ECU (Electronic Control Unit), which is made of single-core architecture, cannot have a higher clock speed. Using multi/many-core architecture is the only way to decrease execution time. However, when implementing the engine control software, various problems occur in utilization of the multi/many-core ECU. One of the biggest problems is sequential structure of control software because the software can only execute with one core on the multi/many-core ECU. The purpose of this paper is to describe the parallelized control design method for discrete-time Models, which has decomposed sequential structure and decreases execution time in the embedded multi/many-core mass production ECU.

13:40-14:00 ThA2.3

Application of Robust Control Barrier Function with Stochastic Disturbance Model for Discrete Time Systems (I), pp. 46-51

Takano, Rin — Tokyo Inst. of Tech
Oyama, Hiroyuki — Tokyo Inst. of Tech
Yamakita, Masaki — Tokyo Inst. of Tech

For engine control systems, there are several constraints to prevent damages of engines due to bad phenomena, eg. knocking. When the dynamics of the systems are modeled as state space representations, the constraints can be represented as state constraints. Therefore, many researchers have studied controllers to achieve good control performances without violating given state constraints. Recently, a new method to solve such constraint control problems has been proposed, which is called CLF-CBF-QP. The control method was proposed rst for continuous time systems and was extended to discrete time systems. It can achieve good control performances in the nominal case, however it is impossible to achieve good results in the presence of disturbances. This paper proposes a robust constrained stabilization control using control barrier function and Gaussian process regression for discrete time systems affected by stochastic disturbances, and show an application to the engine control systems.

14:00-14:20 ThA2.4

Boundary Modeling and Identification of Normal Operation for Automobile Engine (I), pp. 52-56

Yamazaki, Masahiro — Tokyo Denki Univ
Sato, Kotoru — Tokyo Denki Univ
Shinozaki, Katsuya — Tokyo Denki Univ
Iwase, Masami — Tokyo Denki Univ

In this research, we aim to identify a dynamic boundary model which is capable of discriminating the knocking in a transient state of an automobile engine. We derive how to represent transient phenomena specified from definition formula of the knocking. Models of a piston-crank, combustion and an air intake system are utilized to estimate variables concerned with the transient phenomena from measurable information. For this estimation, an in-cylinder pressure is estimated by applying the Unscented Kalman Filter from a crankshaft angle. In addition, the unburned gas temperature is calculated using the estimated in-cylinder pressure. The effectiveness of the proposed method was verified by comparing both estimated results and calculated results with measured data from an engine simulator.

14:20-14:40 ThA2.5

On Quantifying the Utility of Look-Ahead Data for Energy Management (I), pp. 57-62

Hegde, Bharatkumar — The Ohio State Univ
Vallur Rajendran, Avinash — The Ohio State Univ
Ahmed, Qadeer — The Ohio State Univ
Rizzoni, Giorgio — Ohio State Univ

Connectivity and technology integration focused on autonomy and safety in vehicles have equipped many vehicles with a host of sensors. Some of these sensors have the potential to aid energy management strategies by providing useful look-ahead data. Road features like speed limits, road grade, traffic sign locations etc. make up the look-ahead data for energy management. In this paper we quantify the utility of the look-ahead data in fuel economy improvements. The traffic-powertrain co-simulator provides the simulation framework necessary for our analysis. The methodology includes a look-ahead data based velocity predictor and an MPC based look-ahead controller to determine the fuel economy improvement with each look-ahead data. The results of the analysis indicate the existence of a Pareto front for fuel economy improvements with increased look-ahead data.

14:40-15:00 ThA2.6

Symbolic Statistical Analysis of Cylinder-To-Cylinder Imbalance in Gasoline Engine (I), pp. 63-67

Xu, Zidan — Sophia Univ
Shen, Tielong — Sophia Univ

Lean combustion in Spark-ignition (SI) engines has long been recognized as an effective way to improve fuel economy and reduce pollutant emissions. However, servere cyclic variation as combustion mixture being leaned out causes cylinder-to-cylinder imbalance, which may further leads to poor engine performance. In this paper, cylinder-to-cylinder imbalance in lean combustion has been analyzed using symbol statistics. The results shows that while determinism in cyclic variation increases as diluted level increases, deterministic features in inter-cylinder imbalance weakens at lean condition.

ThA3 The 2nd Meeting Room In South Zone

Control Strategies for Electronic Machine and EVs (Regular session)

Chair: Zhang, Weimin — Tongji Univ
Co-Chair: Chen, Yong — Beijing Inst. of Tech

13:00-13:20 ThA3.1

Permanent Magnet Motor Temperature Compensated Constant Torque Control, pp. 68-70

Ma, Zhimin — ZHEJIANG VIE SCIENCE & Tech. CO., LTD,
Qi, Xiaogang — ZHEJIANG VIE SCIENCE & Tech. CO., LTD,

Temperature variation changes the flux remanence in the permanent magnets, the residual flux density of ferrite and neodymium magnet will decrease 19% and 12% with a temperature change of 100 degree. For electric motors with permanent magnet establishing the flux, the torque output of the motor will decrease with temperature rise if only the current is held constant. The permanent magnet synchronous motor are the most popular ones used in the electric vehicles for their efficiency, the usual way these motors are controlled is that the current is controlled according to the reference command, since torque is directly proportional to the current. The drawback is that if the temperature variation is nonnegligible, the torque output of the motor will vary noticeably with different temperatures. This article first analyzes the effect of temperature change on the motor; a control method is then introduced to compensate this effect.

13:20-13:40 ThA3.2

Research on Torque Control Strategy for Electric Vehicle with In-Wheel Motor, pp. 71-74

Geng, Cong — Beijing Jiaotong Univ

Stability control of electric vehicle with in-wheel motor becomes spotlight for it is more convenient to implement the independent 4 wheel torque control. There are two main control strategies according to the vehicle state feedback control parameters. One is single-parameter control based on vehicle yaw rate. The other control strategy is double-parameter control based on combination of vehicle yaw rate and body slip angle. Among the in-wheel-motor EV stability control researches, most of them are based on yaw rate control. The combination algorithm of yaw rate and body slip angel control is less iterative. In addition, there is still lacking of considering the constraint conditions of motor torque characteristic and road adherence. This paper will perform deeper research on these topics. The BP neural network PID algorithm torque distribution control strategy for electric vehicle with in-wheel motor is proposed, in which the constraint conditions of motor torque characteristic and road adherence are taken into concerned. The model-matching control is adopted using double parameters of yaw rate and body slip angle which is adjusted according to weight factor. In addition, the more effective 3-freedom vehicle model is implemented to determine the desired vehicle yaw rate and body slip angle by considering the variation of the tire lateral slip stiffness which is affected by wheel vertical load transfer when vehicle is accelerating and steering. The simulation results show the effectiveness of the torque distribution control strategy. The driver's driving task is performed in the way that vehicle high dynamic performance is satisfied under the condition of ensured vehicle stability.

13:40-14:00 ThA3.3

Estimation of Permanent Magnet Synchronous Machine Performance for Pre-Design Using a Reluctance Network, pp. 75-80

Rechkemmer, Sabrina Kathrin — Univ. of Stuttgart
Izumi, Ryosuke — Toyohashi Univ. of Tech
Zhang, Weimin — Tongji Univ
Sawodny, Oliver — Univ. of Stuttgart

Flexible and fast development processes are required to adapt to changing user and market requirements. This is also true for the design of electric machines. Typically, many different parameter setups like rotor and stator diameter, teeth width, and number of windings,have to evaluated until a suitable motor design is found. As performance estimation is often conducted using finite element analysis (FEA), which is computationally and time intensive, the process takes a long time. Reluctance networks (RNs), on the other hand, simplify the model description but are less accurate than FEA. The aim of this paper is to show that an RN might show larger deviations to the actual motor performance, but can be used in a pre-design step to limit the parameter domain for FEA simulations if the influence of parameter changes is predicted well. Analytical dependencies between motor geometry and model parameters are derived based on a simplified RN and validated using FEA.

14:00-14:20 ThA3.4

Stability Control Based on Sliding Mode Control and Optimized Control Allocation for an Eight In-Wheel Motor Drive AWS Electric Vehicle, pp. 81-86

Wang, Zhifu — Beijing Inst. of Tech
Wang, Xuran — Beijing Inst. of Tech
Huang, Kanglun — Beijing Inst. of Tech
Chen, Yong — Beijing Inst. of Tech

This paper takes an eight in-wheel motor independent drive and all-wheel independent active steering vehicle as research object, and proposes a hierarchical optimized tire force distribution control strategy (8WD8WS+) based on sliding mode control (SMC) and control allocation (CA) to coordinate the output torque and steering angle of all eight wheels. The hierarchical control strategy includes the upper vehicle motion controller, the middle tire force distribution controller and the lower expected tire force tracking controller. The upper controller is based on the sliding mode control algorithm. The middle controller is based on the optimized control allocation method. The lower controller is based on the inverse tire model and the sliding mode control algorithm to achieve the desired wheel slip rate and tire force tracking. Finally, the MATLAB/Simulink model was established to verify the control strategy. The closed-loop double-shift simulation at high speed verified the effectiveness of the control allocation strategy.

14:20-14:40 ThA3.5

A Novel Four-Wheel-Drive Hybrid Electric Sport Utility Vehicle with Double Planetary Gears, pp. 87-92

Ju, Fei — Nanjing Univ. of Science and Tech
Zhuang, Weichao — Southeast Univ
Wang, Liangmo — Nanjing Univ. of Science and Tech
Jiang, Yi — Nanjing Univ. of Science and Tech

Hybrid technology must be applied to Sport Utility Vehicles (SUVs) to meet the stringent fuel economy and emission regulations in the near future. Current hybrid SUVs realize four-wheel-drive (4WD) function which could improve its drivability and handing stability, by adding a motor to the rear axle of conventional series, parallel and power-split hybrid architectures. However, the extra motor incur more cost for the hybrid powertrain. In this paper, a novel hybrid powertrain with double outputs is proposed for 4WD SUVs, which uses a pair of planetary gears to couple the gasoline engine, two electric machines, and both front and rear wheels. The dynamics of this hybrid powertrain is built up and analyzed firstly, then Dynamic Programming (DP) is used to calculate the optimal controls and best fuel economy. Results indicates this 4WD hybrid powertrain shows greater fuel economy improvement than conventional 4WD system.

14:40-15:00 ThA3.6

A Modeling Method of Whole Vehicle Electrical Balance Simulation System Based on Neural Network Training, pp. 93-97

Wang, Hongyu — FAW Liberation Co., Ltd. Commercial Vehicle Development Inst
Yue, Yupeng — FAW Jiefang Automobile Co, Ltd. Commercial Vehicle Development A
Ma, Chuang — FAW Liberation Co., Ltd. Commercial Vehicle Development Inst

With the rapid development of automotive electronic and electrical technology, the electronic configuration of automotive systems is gradually increased, resulting in a serious imbalance between the power generation and consumption in the vehicle power network. Vehicle electrical balance test is to verify whether the vehicle power system matching status can meet the design requirements. The traditional vehicle electrical balance test can only be carried out after the electronic and electrical functions of the whole vehicle are complete and the electronic and electrical system has no replacement parts. This paper proposes a modeling method of vehicle electrical balance simulation system, which can intervene in part of the test in the early stage of design, and play an aided guidance role for the vehicle power system design. The simulation system is put up through Simulink. The neural network module is used for data training, and the state-flow module is used to realize the running condition circulation which is established from the combined running condition of battery, generator and electric equipments. And a commercial vehicle of FAW is used for test verification.

ThA4 Meeting Room of Spring Dawn

Closed Loop Combustion Control (Invited session)

Chair: Tunestal, Per — Lund Univ. Faculty of Engineering
Co-Chair: Blanco-Rodriguez, David — FEV GmbH
Organizer: Guardiola, Carlos — Univ. Pol. De Valencia
Organizer: Pla, Benjamín — Univ. Pol. De Valencia

13:00-13:20 ThA4.1

In-Cycle Closed-Loop Combustion Control for Maximum Indicated Efficiency (I), pp. 98-104

Jorques Moreno, Carlos — Scania CV AB
Stenlåås, Ola — Scania CV AB
Tunestal, Per — Lund Univ. Faculty of Engineering

An in-cycle closed-loop combustion controller is proposed in this paper. The controller uses a pilot-main injection scheme where the cycle-individual properties of the pilot combustion are estimated by in-cylinder pressure measurements, and used to predict their effect on the heat release shape of the main combustion. The prediction is used to obtain the optimal main SOI that gives the Maximum Reachable Indicated Efficiency (MRE). The optimal law was linearised to obtain a linear controller that adjusts the main SOI and main duration to obtain the MRE given the conditions of each cycle. The controller was implemented in an FPGA and tested on a Scania D13 Diesel engine. The results show that the main SOI control improves the indicated efficiency. However, the linear controller application is limited due to the non-linear behaviour of the system, which is dependent on the fuel type.

13:20-13:40 ThA4.2

Linear Stochastic Modeling and Control of Diluted Combustion for Spark Ignition Engines (I), pp. 105-110

Maldonado, Bryan — Univ. of Michigan
Stefanopoulou, Anna G. — Univ. of Michigan

The combustion process in spark-ignition (SI) internal combustion engines exhibits cycle-to-cycle variability, which imposes limits on engine operation. When exhaust gas recirculation (EGR) is used to increase engine efficiency, the combustion variability (CV) increases and spark advance (SA) must be re-tuned to achieve maximum brake torque. In order to maximize EGR benefits without excessive cyclic CV, feedback control can be applied to modify EGR and SA accordingly. The closed-loop system, however, propagates the CV from the measurements to the control commands and could increase the overall cyclic variability. This paper presents a control-oriented combustion model that captures the stochastic properties of combustion features. A linear quadratic Gaussian (LQG) controller is used to modify SA and EGR to achieve a particular combustion shape, characterized by the initiation and duration angles. Using stochastic control theory for linear Gaussian system, analytical solutions for the cyclic variability of the combustion process and the control commands under closed-loop operation are derived. This methodology is validated against experimental engine data and results at transient and steady state operation are presented.

13:40-14:00 ThA4.3

Combustion Variation Feedback Control Approach for Multi-Cylinder Spark Ignition Engines (I), pp. 111-116

Zhang, Yahui — Sophia Univ
Shen, Tielong — Sophia Univ

Lean-burn is an important advanced technology that is of benefit to the efficiency improvement of spark ignition (SI) engines. However, the combustion variation is a major barrier to achieving leaner air/fuel ratio. This paper presents an in-cylinder pressure-based multi-cylinder multi-variable combustion variation control strategy for SI engines, aims at controlling the combustion to the target heat release pattern (HRP). The combustion phase and total heat release are chosen as the control parameters which are controlled by adjusting spark advance (SA) and fuel injection mass, respectively. Two separate close-loop statistical controllers are designed for SA and fuel injection control of a cylinder. The designed controllers are then applied to every individual cylinder. The effectiveness of the presented individual cylinder control strategy is finally validated on a production SI gasoline engine at lean-burn mode.

14:00-14:20 ThA4.4

Is Cylinder Pressure-Based Control Required to Meet Future HD Legislation? (I), pp. 117-124

Willems, Frank — Eindhoven Univ. of Tech

This work aims to determine the potential and benefits of cylinder pressure-based control (CPBC) to meet future emission legislation for heavy-duty automotive applications. Focus is on resulting engine performance. From a literature study, it is seen that CPBC is a

crucial enabler for ultra high efficient and clean combustion concepts, such as PPC and RCCI. For these advanced concepts, combustion phasing and heat release control is key to guarantee stable and safe operation. RCCI also supports the transition towards sustainable fuels by allowing for the use of a wide range of fuels. In addition, CPBC is seen to reduce the calibration effort and to improve performance robustness for all combustion concepts. This results in reduced engine out emission dispersion and improved torque response. Installation of cylinder pressure sensors opens the route to real-time and robust estimation and monitoring of fuel efficiency, combustion noise, and NOx and opacity emissions. This permits new OBD functionality and sensor removal, and thus system cost reduction. For PPC and RCCI, the main control challenges are stable operation with maximal efficiency over the full load range, transient control, and fuel flexibility. To fully exploit the CPBC potential, better understanding of coordinated air-fuel path control, self-learning control capabilities for on-line fuel optimization, and in-cycle control of the heat release shape is needed.

14:20-14:40 ThA4.5

A Combustion Phasing Control-Oriented Model Applied to an RCCI Engine (I), pp. 125-130

Guardiola, Carlos — Univ. Pol. De Valencia
Pla, Benjamín — Univ. Pol. De Valencia
Bares, Pau — Univ. Pol. De Valencia
Barbier, Alvin — Univ. Pol. De Valencia

Low temperature combustions such as Reactivity Controlled Compression Ignition (RCCI) have been shown to be a promising way to reduce pollutants at the exhaust, i.e. NOx and soot emissions, and increase the thermal efficiency of future engines. However, such concepts are subject to substantial control sensitivity, e.g. combustion phasing, due to their lack of direct actuation for controlling the ignition of the mixture. This work investigates a control-oriented model based on physical equations aimed to predict the start of combustion and the crank angle of 50% fuel burnt (CA50). The model was developed for predicting the ignition using a modified knock integral model and a linear equation was used to estimate the burn duration between the start of combustion and the combustion phasing. The calibration and the validation of the model were performed using experimental data from a heavy-duty engine showing good results under transient operation.

14:40-15:00 ThA4.6

Stochastic Knock Control with Beta Distribution Learning for Gasoline Engines (I), pp. 131-136

Zhao, Kai — Sophia Univ
Wu, Yuhu — Dalian Univ. of Tech
Shen, Tielong — Sophia Univ

Knock phenomenon as a stochastic process requires feedback control for its relation to engine efficiency, noise and cylinder damage. In this paper, a knock probability estimation method using Bayes' updating rule and beta distribution is proposed based on the independent and identically distributed (iid) characteristic analysis of the knock event sequence. A stochastic control algorithm using the estimation method and likelihood ratio test is also proposed. The proposed control algorithm is validated on a production spark ignition engine and shows the ability to maintain knock probability close to the target.

ThA5 — The 2nd Meeting Room In North Zone

Nonlinear Intelligent Control of Automobile (Invited session)

Chair: Rui, Bai — Liaoning Univ. of Tech
Co-Chair: Shen, Xun — Sophia Univ
Organizer: Rui, Bai — Liaoning Univ. of Tech

13:00-13:20 ThA5.1

Nonlinear Control for Semi-Active Suspension with Input Constraints (I), pp. 137-141

Sun, Liying — Liaoning Univ. of Tech
Wang, Xin — Electrical Engineering Coll. Liaoning Univ. of Tech

A nonlinear controller design method based on quarter-car model of semi-active suspension is proposed for input constraints problem. Taking the system nonlinear characteristics and input constraints into account sufficiently, an auxiliary system is introduced to combine backstepping method to cut down vibration of semi-active suspension. In the design process, we use a Nussbaum function to compensate for the nonlinear term arising from the input constraints. Due to the absence of any linearization method, the control input is limited to a certain range while maintaining the nonlinear characteristics of the system. The simulation results show that the suspension system can move toward stability quickly in the condition of input saturation, and can effectively improve the ride quality of the vehicle.

13:20-13:40 ThA5.2

Fuzzy Adaptive Backstepping Control for a Class of Active Suspension Systems (I), pp. 142-147

Sun, Hao — Liaoning Univ. of Tech
Li, Yongming — Liaoning Univ. of Tech
Tong, Shaocheng — Liaoning Univ. of Tech
Xu, Kun — Liaoning Univ. of Tech

In this paper, an adaptive backstepping method is used to research the vehicle active suspension control. At a quarter active suspension of vehicle consider control of fourth-order system. Piecewise linear damper and nonlinear spring are approached by fuzzy logic system for accuracy control. The method can ensuring safety while improves comfort.

13:40-14:00 ThA5.3

Fuel Economic Dual-Mode Predictive Control for Autonomous Vehicles in Urban Road Conditions, pp. 148-153

He, De-feng — Zhejiang Univ. of Tech
Shi, Yujie — Zhejiang Univ. of Tech
Song, Xiu-lan — Zhejiang Univ. of Tech
Yu, Shiming — Zhejiang Univ. of Tech

The paper considers the fuel economic driving optimization problem of autonomous vehicles in urban road conditions and proposes a dual-mode model predictive control strategy for fuel economy of the vehicle. Along with the V2X wireless communication technology, the signal phase and timing information from traffic lights is employed to compute the optimal velocity by the fuel economic polynomial model. Then we combine the dual-mode control strategy to formulate the finite horizon fuel economic optimal control problem of the autonomous vehicle. In order to guarantee feasibility and closed-loop stability of the fuel economic model predictive control strategy, control Lyapunov functions of nonlinear systems with respect to the optimal velocity is used to parameterize the predictive control law by finite degrees of freedom. By compressing the number of the decision variables of the fuel economic optimal control problem, the computational burden of the fuel economic model predictive control strategy is reduced. Finally, some simulation experiments are used to illustrate the effectiveness of the proposed method.

14:00-14:20 ThA5.4

Design of Hardware-In-Loop Simulation Platform for Air Suspension Systems (I), pp. 154-157

Wang, Hebin — Liaoning Univ. of Tech
Rui, Bai — Liaoning Univ. of Tech

With the development of control algorithms and structural features in the control system, the hardware-in-loop simulation technology has been widely used after unremitting research and exploration on the basis of off-line simulation. In this paper, the dSPACE real-time simulation system is used to design and develop a hardware loop simulation experiment platform for an air suspension. CarSim vehicle model and suspension control algorithms can be run in the real time. Based on the dSPACE real-time simulation platform mentioned above, a real-time monitoring interface and control program are developed to complete the test of the sliding mode control method of the 1/4 air suspension.

14:20-14:40 ThA5.5

Fuzzy-Based Direct Adaptive Tracking Control of Non-Affine Stochastic Nonlinear Systems without Triangular Form (I), pp. 158-163

Wang, Huanqing Bohai Univ
Shan, Licheng Bohai Univ

This paper is concerned with fuzzy adaptive control of pure-feedback stochastic nonlinear systems with Prandtl-Ishlinskii hysteresis. The mean-value theorem is applied to deal with the difficulty from non-affine structure in generalized Prandtl-Ishlinskii hysteresis and original control systems. An adaptive fuzzy control scheme with minimum learning parameter is developed via backstepping. The proposed controller ensures the semi-global boundedness in fourth-moment of all signals in the closed-loop system and the system output converges to a small area of the given trajectories. Simulation results are presented to demonstrate the effectiveness of the scheme.

14:40-15:00 ThA5.6

Cooperative Control of a UGV Platform and Performance Experimental Validation (I), pp. 164-168

Ni, Jun Beijing Inst. of Tech
Hu, JiBin Beijing Inst. of Tech
Zhao, Yue Beijing Inst. of Tech
Pan, Bo Beijing Inst. of Tech
Li, Yunxiao Beijing Inst. of Tech

This paper reports a collaborative system with UAVs, a UGV Platform, and a ground robots, which is called unmanned ground carrier (UGC). The UGC is able to conduct complex mission through the collaborative remote control between the UGV platform, UAVs, and ground robots. The details of the design of the UGV platform and the carried flying robot are described. The experiments show the functions of the UGC and performance of the collaborative controller between the UGV platform, flying robot, and ground robot.

ThA6 The 3rd Meeting Room In South Zone

Applications of Advanced Control Technologies to Engines and Vehicles (Invited session)

Chair: Gao, Jinwu Jilin Univ
Co-Chair: Canova, Marcello The Ohio State Univ
Organizer: Li, Suwen Company

13:00-13:20 ThA6.1

Primary Study on the Transient EGR Control of GDI Turbocharged Engine by Ion Sensing Technology, pp. 169-176

Zhu, Denghao Tongji Univ
Chao, Yuedong Tongji Univ
Chen, Zhilin Tongji Univ
Deng, Jun Tongji Univ
Li, Liguang Tongji Univ

Based on a 1.0L turbocharged GDI engine and self-designed ion current detection system, the potential of using ion sensing technology for transient EGR control is studied. Firstly, ion sensing performance under steady-state EGR condition is studied. The result shows that there is a highly correlation between ion current signal and EGR variation, but the big cyclic variation of ion current signal makes it impossible to be used for control. Thus, the moving average signal processing method is proposed, and the cyclic variation of ion current signal could be reduced to the same level as cylinder pressure signal. Based on that, ion sensing and UEGO sensor performance under typical transient EGR condition is compared. The weighted moving average method is proposed optimized from the moving average method to shorten the response delay of ion current signal without affecting the cyclic variation. Finally, the applicability of ion current signal under different operating conditions is studied. The result shows that ion current signal could be used for transient EGR control. However, if the variation of ion current signal caused by EGR is within the cyclic variation range of ion current signal, the variation of EGR is hard to be distinguished, especially under low load condition.

13:20-13:40 ThA6.2

Nonlinear Compensation Method for Injector in Small Flow Area on GDI Engine (I), pp. 177-180

Wang, Qiang General R&D Inst. of China FAW Co., Ltd
Xin, Baiyu General R&D Inst. of China FAW Co., Ltd
Li, JiaLing General R&D Inst. of China FAW Co., Ltd
Sun, PengYuan General R&D Inst. of China FAW Co., Ltd
Liu, Qifang Jilin Univ

In this paper, through the analysis of the driving principle of the injector, we designed a nonlinear compensation method to improve the precision of the injection control and optimizes the emission of the gasoline direct injection (GDI) engine. Then this method is verified on the 4GA12TD engine which is developed by FAW.

13:40-14:00 ThA6.3

Emission Control Method for Fuel Cut-Off Condition of GDI Engine (I), pp. 181-184

Xin, Baiyu General R&D Inst. of China FAW Co., Ltd
Li, JiaLing General R&D Inst. of China FAW Co., Ltd
Wang, Qiang General R&D Inst. of China FAW Co., Ltd
Sun, PengYuan General R&D Inst. of China FAW Co., Ltd
Liu, Qifang Jilin Univ

As an effective device to improve emissions for gasoline engine, the catalyst has been widely applied in vehicles. Long time fuel cutoff condition will lead to the increase of oxygen content in catalyst. To improve the emission performance after fuel cutoff recover, a control method of purging oxygen in catalyst is proposed in this paper. The model of oxygen storage and purge is built. Then a state machine of oxygen purge is designed based on this model. Finally, the strategy is applied on the real vehicle test. Through the test results under the NEDC driving cycle, it is shown that the proposed method of catalyst oxygen purge can effectively reduce the emission for GDI engine.

14:00-14:20 ThA6.4

Scavenging Control Method of Turbo GDI Engine (I), pp. 185-188

Li, JiaLing General R&D Inst. of China FAW

Co., Ltd
Xin, Baiyu — General R&D Inst. of China FAW Co., Ltd
Wang, Qiang — General R&D Inst. of China FAW Co., Ltd
Sun, PengYuan — General R&D Inst. of China FAW Co., Ltd

In this paper, the scavenging concepts and scavenging control scheme in GDI engine is introduced, and then the strong scavenging and weak scavenging control function is designed in detail. From the test results on FAW technology center GDI engine test-bench, the scavenging control method is verified effectively. And the small-displacement GDI engine torque and the power performance can be improved in the scavenging conditions.

14:20-14:40 ThA6.5

A Physics-Based Three-Way Catalytic Converter Model for Real-Time Prediction of Temperature Distribution, pp. 189-194

Zhu, Zhaoxuan — The Ohio State Univ
Midlam-Mohler, Shawn — Ohio State Univ
Canova, Marcello — The Ohio State Univ

Thermal management of aftertreatment devices is a critical requirement to comply with the stringent emission standards. A recent challenge in aftertreatment control and diagnostics is the need to monitor the temperature distribution along the entire length of the catalyst, rather than relying on a single-point measurement. To this extent, this work focuses on the preliminary development of a control-oriented, physics-based Three-way Catalytic Converter (TWC) model for the purpose of real-time thermal monitoring. Starting from the governing equations for the TWC thermal model in Partial Differential Equation (PDE) form, a model order reduction technique that combines Proper Orthogonal Decomposition and Collocation is proposed. The reduced order model executes much faster than using standard numerical methods, and meanwhile provides comparable accuracy. The model is also validated against GT-Power in the ability to predict the temperature distribution during cold-start conditions.

14:40-15:00 ThA6.6

A Noise Reduction Method for MEMS Gyroscope Based on Direct Modeling and Kalman Filter, pp. 195-199

Cai, Shuo — Jilin Univ
Hu, Yunfeng — Jilin Univ
Ding, Haitao — Jilin Univ
Chen, Hong — Jilin Univ. Campus NanLing

This paper focus on the topic of reducing the random noise in the output data of MEMS gyroscope and improving the accuracy of MEMS gyroscope. Aiming at the problems that the previous methods are not suitable for dynamic data and difficult to realize real-time online processing, a direct modeling method is proposed to establish the output data model of MEMS gyroscope. Based on this model, the kalman filter is designed to process the output data. The experimental results show that the proposed method has good performance on both static data and dynamic data.

ThE1 Conference Room of Pine Billows

Hybrid and Electric Vehicles II (Invited session)

Chair: Kako, Junichi — Toyota Motor Corp
Co-Chair: Zhang, Jiangyan — Dalian Minzu Univ

15:20-15:40 ThE1.1

Improving the Electrified Powertrain Performance Based on Retrospective Behaviour of Battery State of Charge and Engine Fuel Consumption (I), pp. 200-205

Li, Xuchen — The Ohio State Univ
Ahmed, Qadeer — The Ohio State Univ
Rahman, Yousaf — Ford Motor Company

Vehicle performance, including battery charge sustaining operation and engine fuel economy improvement, is dependent on how its powertrain controller is tuned for different road loads, which is hard to predict. However, if historical data is analyzed and used to fine tune the energy management strategy coefficients, vehicle powertrain performance can be enhanced. This paper presents a retrospective performance-based powertrain controller which is dependent on a conflicting cost function. The cost function depends on a charge sustaining operation of the onboard battery and engine fuel consumption. The proposed Retrospective Cost Adaptive Controller (RCAC) has been designed for a parallel HEV, which improves powertrain performance based on its historical performance. The numerical simulation results demonstrate that the powertrain controller coefficients are re-calibrated to improve powertrain performance. It is also shown that the once the RCAC learns the driving styles, the powertrain performance is comparable to benchmark results generated using Dynamics Programming.

15:40-16:00 ThE1.2

Receding Horizon Optimal Control of PHEV with Demanded Torque Estimation Model (I), pp. 206-210

Zhang, Jiangyan — Dalian Minzu Univ
Shen, Tielong — Sophia Univ

This paper proposes a real-time optimization method for the energy management of a plug-in hybrid electric vehicle (PHEV). Focusing on a parallel PHEV and the total energy consumption minimization of on-road driving operation, a suitable control scheme that combining a rule-based block for operation modes decision and a low-level model predictive control (MPC) algorithm to manage the transient operation during power assistance. During the transient operation, a model with time-varying parameter is introduced to generate the driving torque during the predictive horizon. By using the C/GMRES (Continuation/General Minimum Residual) based algorithm, the proposed nonlinear MPC problem is solved efficiently. Simulation results demonstrate the control performance.

16:00-16:20 ThE1.3

Converting a Conventional Car into a Hybrid Solar Vehicle: A LCA Approach (I), pp. 211-217

Tiano, Francesco Antonio — Univ. of Salerno
Rizzo, Gianfranco — Univ. of Salerno
De Feo, Giovanni — Univ. Degli Studi Di Salerno
Landolfi, Silvio — Univ

The growth of world energy consumption and the increase of passenger vehicles areis setting new challenges to environmental protection. Large diffusion of electric vehicles and hybrid electric vehicles seems to be the most feasible solution. However, the need of fast charging infrastructure, the still low penetration of renewable electricity production and the massive reconversion of fleets limit the feasibility of this solution.

A life-cycle assessment study of several mobility options is presented in the paper. The analyses, performed by the use of the GREET model software, show that a suitable solution to reduction of total energy consumption and greenhouse gases emissions in the short to medium term could be the conversion of conventional vehicles into hybrid solar vehicles, as in the system developed at the University of Salerno.

16:20-16:40 ThE1.4

Energy Analysis of Eco-Driving Maneuvers on Electric Vehicles (I), pp. 218-223

Solano-Araque, Edwin — Univ. D'orléans, PRISME; Renault S.A.S

Colin, Guillaume — Univ. Orléans
Cloarec, Guy-Michel — Renault SA
Ketfi-Cherif, Ahmed — Renault
Chamaillard, Yann — Univ. of Orléans

We present an approach allowing us to compare the energy consumption of an electric vehicle (EV) in different maneuvers of driving scenarios. This approach is used in order to estimate the potential of Eco-driving for reducing EV consumption, and also to analyze where this gain comes from. Drivability constraints were taken into account in the study. We present energy loss distribution among the different components of the vehicle. In simulations, we considered cruising, acceleration and deceleration scenarios in urban driving. Results seem to show that reducing driver aggressiveness on accelerations is the main factor in reducing EV consumption in urban settings.

16:40-17:00 ThE1.5

Hybrid Vehicle Control and Optimization with a New Mathematical Method (I), pp. 224-229

Tateiwa, Nariaki — Kyushu Univ
Hata, Nozomi — Kyushu Univ
Tanaka, Akira — Kyushu Univ
Yoshida, Akihiro — Kyushu Univ
Wakamatsu, Takashi — Faculty of Mathematics, Kyushu Univ
Nakayama, Takashi — Kyushu Univ
Fujisawa, Katsuki — Kyushu Univ

For hybrid electric vehicle (HEV) systems, studies using model-based simulators have been actively conducted. The vehicle powertrain simulator makes it easier to evaluate the powertrain system. In this paper, we utilize a Toyota Hybrid System (THS) simulator to obtain a long-term control that optimizes the fuel efficiency when the vehicle speed over a certain period is given. Our proposed method obtains optimal long-term control by solving the shortest path problem with state of charge (SOC) constraints after constructing a graph expressing the transition of the fuel and battery consumption. We also propose a search method for vehicle control using bicubic spline interpolation without the preparation of a controller. We finally remove almost all edges from a graph by 97.2% at most through the utilization of 0-1 integer linear programming, which enables a 3.88x speedup in obtaining the optimal vehicle control.

17:00-17:20 ThE1.6

Research of the Optimization Methodology for the Advanced Powertrain Control (I), pp. 230-235

Kako, Junichi — Toyota Motor Corp
Yoshida, Shozo — Toyota Motor Corp
Tsunogawa, Hiroki — Toyota Motor Corp
Shimizu, Rio — Toyota Motor Corp

Vehicle powertrain system is expected to become more complex because they tend to be electrified in order to be more clean and fuel-efficient. For advanced powertrain planning, we have to choose best powertrain system from among many candidates expected by evaluating their potential correctly. It is necessary to make detailed controller for correct system evaluation. But it is very hard and time consuming. In this study, powertrain potential prediction methodology is proposed. With this methodology, it is possible to achieve best input time trace without any detailed controller by optimize system control input directly.

17:20-17:40 ThE1.7

Modeling of a Hybrid Powertrain with a Stepped Automatic Transmission (I), pp. 236-241

Bauer, Michel — Univ. of Stuttgart
Sawodny, Oliver — Univ. of Stuttgart

In this paper a physics-based overall model of a hybrid powertrain equipped with a stepped automatic gearbox is derived. On the one side, the model approach serves as plant model for the development of new control strategies for clutch-to-clutch gear shifts. On the other side, it provides important insight into the dominant dynamic effects. This study focuses on wet clutches and their hydraulic actuation as well as a compact mathematical representation of the planetary gear train. The use of a modified elasto-plastic friction model allows for a physical representation of the friction torque occurring during gear shifts without the need of structural model changes.

ThE2 Convention Room of Pines

Engine and Powertrain Control II (Invited session)

Chair: del Re, Luigi — Johannes Kepler Univ
Co-Chair: Willems, Frank — Eindhoven Univ. of Tech
Organizer: Waschl, Harald — Johannes Kepler Univ. Linz
Organizer: Willems, Frank — Eindhoven Univ. of Tech

15:20-15:40 ThE2.1

Model Based Diesel Injection Profile Optimization to Reduce Transient Soot Peaks (I), pp. 242-247

Großbichler, Martin — Johannes Kepler Univ. Linz
Polterauer, Philipp — Johannes Kepler Univ. Linz
Zhang, Zhen — AVL
Waschl, Harald — Johannes Kepler Univ. Linz
del Re, Luigi — Johannes Kepler Univ

To meet current legislation limits, modern Diesel engines achieve low raw emission levels and utilize complex aftertreatment systems. Still, during fast transients undesired emission peaks may occur for both soot and NOx. These are caused by deviations in the in-cylinder conditions between the quasi steady engine calibration and the transient operation, e.g. during tip-ins. In this work a case study is performed to analyze the potential reduction of transient soot emissions during a specified engine maneuver. An additional target is to investigate potential benefits of a novel in-situ soot sensor based on the Laser Induced Incandescence (LII) principle which offers a high temporal resolution. Measurement data from a Diesel engine is used to develop time varying setpoint deviation models which will be utilized in a numerical optimization problem to determine an optimized injection profile. The modeling and optimization is carried out in parallel for both sensors and results are compared against each other. In the experimental validation the optimized injection profiles were capable of reducing undesired overshoots during transients with minimal impact on the torque response. Furthermore, the novel sensor allows to gain additional insights in the relation between input parameters and soot response, which is reflected by the obtained models and control action.

15:40-16:00 ThE2.2

Robust Fuel Consumption Estimation for On-Line Optimization of Diesel Engines (I), pp. 256-262

Kupper, Frank — TNO Automotive
Forrai, Alexadru — TNO
Indrajuana, Armando — TNO Automotive
van der Weijst, Robert — Eindhoven Univ. of Tech
van Keulen, Thijs Adriaan Cornelis — Tech. Univ. Eindhoven
Willems, Frank — Eindhoven Univ. of Tech

Accurate estimation of Brake Specific Fuel Consumption (BSFC) is required to enable on-line optimization of real-world fuel efficiency of diesel engines. This work aims to develop a BSFC estimation

method which is accurate enough for an adaptive controller for on-line engine optimization, e.g., using Extremum Seeking. In this paper two different BSFC estimation methods are evaluated: A heat-release based method using in-cylinder pressure sensors and an approach based on injector opening time. Analysis of the two approaches shows that the injector opening time approach yields the highest accuracy. This method together with an adaptive controller is validated experimentally on a Euro-VI diesel engine. Experimental results show that the BSFC estimation is robust against variations in combustion phasing and scavenging losses. The estimated location, in terms of combustion phasing and scavenging losses, of the BSFC minimum remains within 0.1% relative error with respect to the measured BSFC minimum.

16:00-16:20 ThE2.3

Electric-Motor-In-The-Loop: Efficient Testing and Calibration of Hybrid Power Trains (I), pp. 263-268

Klein, Serge — RWTH Aachen Univ
Xia, Feihong — RWTH Aachen Univ
Etzold, Konstantin — RWTH Aachen Univ
Andert, Jakob — RWTH Aachen Univ
Amringer, Nicolas — Dspace GmbH
Walter, Stefan — Dspace GmbH
Bellanger, Claudia — ESI ITI GmbH
Blochwitz, Torsten — ESI ITI GmbH

New electric and hybrid vehicle propulsion architectures require the application of sophisticated control algorithms. The calibration and the testing of these control algorithms is nearly as important and time consuming as the development of the algorithms itself. Testing with the real vehicle is very expensive and only possible in late development stages. Calibration and testing tasks can be shifted to earlier phases by using precise co-simulation and Hardware-in-the-Loop (HiL) approaches. This study shows the advantages of frontloading of development tasks by implementing a virtual P2-Hybrid in an Electrical-Motor-in-the-Loop test bench. As baseline, a state of the art vehicle co-simulation is used. The simulation setup is composed of a GT-Power engine model, a dSPACE vehicle dynamics model and a SimulationX powertrain model. This conventional model is extended by a virtual electrical motor and a hybrid control unit. With the pure Model-in-the-Loop simulation, some calibration and testing tasks are possible, but the simulation lacks of some complex physical properties, e.g. the thermal behavior of the electrical motor. In a next step, the virtual electrical motor is replaced by a real electrical motor on a test bench. The residual simulation is interacting in real-time with the real electrical motor. This enables the possibility to calibrate all relevant controllers to the real component under realistic and dynamic circumstances including mutual interaction of calibration parameter and the physical device under test.

16:20-16:40 ThE2.4

Hierarchical Optimal Vehicle Control for Known Routes (I), pp. 269-274

Polterauer, Philipp — Johannes Kepler Univ. Linz
del Re, Luigi — Johannes Kepler Univ

Autonomous vehicles could bring a significant benefit in terms of fuel consumption and emissions, besides safety and comfort, but the full potential can only be exploited if the appropriate (optimal) control is applied. However complexity of optimal control can prevent its use in practice. Therefore, we suggest to approximate the optimal vehicle control problem by a two-layer structure in which the upper level provides a solution for the reference speed trajectory using energy consumption as cost function, while the lower one optimally tracks the reference speed considering fuel consumption and emissions. The key advantage is the simplicity of the upper layer, which reduces the computational burden, albeit with some expected loss of optimality if compared to the global optimum. The control and results are shown using a model of a production vehicle with a CI engine. The possibility of using this approach to trade-off fuel vs. NO x is discussed. The authors believe that splitting the optimization problem into a multi- layer structure is a sensible approach to enforce computational tractability while recovering part of the optimization potential

16:40-17:00 ThE2.5

Optimal Control Based Falsification of Unknown Systems with Time Delays: A Gasoline Engine A/F Ratio Control Case Study (I), pp. 275-280

Li, Nan — Univ. of Michigan
Girard, Anouck — Univ. of Michigan, Ann Arbor
Kolmanovsky, Ilya V. — Univ. of Michigan

In this paper, we present a falsification scheme for nonlinear systems with input and/or state delays without relying on their explicit models. We formulate the falsification of predefined specifications as an optimal control problem, and exploit a functional gradient based method to solve it. Since the approach does not require an explicit model of the system, it is potentially applicable to industrial models of high complexity or directly to experimental hardware. We consider the falsification of a gasoline engine air-to-fuel ratio control system as a case study.

17:00-17:20 ThE2.6

Fuel and Pollutant Efficient Vehicle Speed Optimization in Real Driving Conditions (I), pp. 248-255

Luján, José Manuel — CMT Motores Termicos, Univ. Pol. De Valencia
Pla, Benjamín — Univ. Pol. De Valencia
Guardiola, Carlos — Univ. Pol. De Valencia
Reig, Alberto — Univ. Pol. De Valencia

This paper analyzes the potential benefits in terms of fuel consumption and NOx emissions of an optimized speed trajectory in a real driving situation. The speed management of the vehicle is approached as an optimal control problem, based on a simplified vehicle model supported by experimental measurements. This optimal control problem is addressed twice on a daily commuting route: one for minimum fuel consumption and another for minimum NOx emissions. These speed trajectories are followed in a vehicle test bench, simulating the actual road conditions, with a fully instrumented vehicle. The experimental results are compared to the way two different drivers perform the same route in the same amount of time with their own natural driving styles. Optimal results demonstrate that optimal speed trajectory is strongly dependent on the minimization objective (either fuel or NOx), and that reductions around 4% in fuel consumption and 35% in NOx emissions were possible in the testing route compared to intuitive human driving styles.

ThE3 The 2nd Meeting Room In South Zone

Estimation and Control for Battery (Regular session)

Chair: Xiong, Rui — Beijing Inst. of Tech
Co-Chair: Liu, Yonggang — Chongqing Univ

15:20-15:40 ThE3.1

An Approach to Internal and External Temperature Estimation for Cylindrical Battery Based on Finite Difference Method, pp. 281-284

Li, Xinggang — Beijing Inst. of Tech
Xiong, Rui — Beijing Inst. of Tech

A method of estimating the temperature for cylindrical battery is expounded. Based on the simplified one-dimensional（1-D） thermal model and the Bernardi heat generate model, the finite difference method is used to calculate the internal and external temperatures

of the battery. And different charge and discharge condition experiments are performed. Comparisons between the estimation results and measured results proved the accuracy of the model. The maximum estimation error is about 4.5℃. Using the measured external temperature of the battery, the internal temperature can be corrected. And the error is within 1℃.

15:40-16:00 ThE3.2

Active Thermal Control of a Battery Pack under Elevated Temperatures, pp. 285-290

Gao, Xiaojing — Department of Control Science and Engineering, Jilin Univ
Ma, Yan — Jilin Univ
Chen, Hong — Jilin Univ. Campus NanLing

This work studies the battery thermal management employing fuzzy logic control(FLC). This work first develops the reduced-order model (ROM) of a battery pack whose heat transfer coefficient varies with coolant flow velocity. Then, the ROM is simplified to obtain the temperature range of battery pack. A computational fluid dynamics (CFD) model is built and validated to verify the accuracy of ROM. Finally, based on the ROM, different control strategies are used to control the temperature of battery pack. ANSYS and MATLAB cosimulation is proposed to validate the effectiveness of FLC. The simulation results suggest that FLC, compared with PID control, rapidly controls the battery temperature in expected value, and ensures temperature control error within 0.2℃.

16:00-16:20 ThE3.3

A Comparative Study of Remaining Useful Life Predictions for Lithium-Ion Battery (I), pp. 291-296

Xiong, Rui — Beijing Inst. of Tech
Lu, Jiahuan — Beijing Inst. of Tech

Remaining useful life (RUL) prediction is a key part of battery health management to ensure vehicle safety and economy. This paper makes a comparative study of four representative RUL prediction methods, including fitting-based method, particle filter (PF) based-method, Box-cox transformation (BCT)-based method and support vector machine (SVM)-based method. A battery degradation experiment is performed to support the comparative study. After the comparative study of on-line battery RUL prediction, BCT shows the best comprehensive performance, while the other three methods have their own application characteristics respectively.

16:20-16:40 ThE3.4

Driving-Style-Oriented Multi-Objective Optimal Control of an Electric Vehicle, pp. 297-301

Yang, Caixia — Chongqing Univ
Lv, Chen — Nanyang Tech. Univ
Shu, Hongyu — Chongqing Univ
Song, Yitong — Chongqing Univ
Wang, Huaji — AVL Powertrain UK Ltd
Cao, Dongpu — Univ. of Waterloo

This paper investigates multi-objective optimization of electric vehicle (EV) based on features extracted from three driving styles, aiming at coordinating dynamic performance, ride comfort and energy efficiency. First, an unsupervised learning approach is used to clusters real-world driving data, obtaining three different driving styles. Then, the preferred performances under distinct driving styles are analyzed, and driving-style-oriented are determined. A model predictive controller is developed so as to handle the formulated multi-objective optimization problem. Simulations are carried out under with the developed controller and system models. Simulation results showed that the proposed controller could well coordinate the dynamic performance, ride comfort and energy efficiency of the 4IWDEV, validating the feasibility and effectiveness of the developed methodology and algorithms.

16:40-17:00 ThE3.5

A Robust Estimation of State of Charge for Electric Vehicle Batteries, pp. 302-307

Zhao, Linhui — Harbin Inst. of Tech
Li, Huihui — Harbin Inst. of Tech
Ji, Guohuang — First Automotive Works
Liu, Zhiyuan — Harbin Inst. of Tech

Knowledge of state of charge (SOC) is extremely important for electric vehicle batteries. This paper proposes a sliding mode observer for reliable and real-time estimation of the SOC. Nonlinear dynamics of the battery is considered, and parametric and modelling uncertainties are modelled as additive disturbances. Robustness performance of the proposed observer is guaranteed using input-to-state stability (ISS) theory. This indicates that the proposed observer is robust against parametric and modelling uncertainties, and can guarantees an upper bounded estimation errors. A designed method of the observer gains is presented following the stability analysis result. The proposed observer is implemented in an embedded hardware based on Freescale MPC5554, and is validated using datasets from a lithium-ion battery under different temperatures. The robustness of the observer against model parameter uncertainties, sensors biases, and measurement noises, which may appear in real vehicles, is evaluated. The experimental and robustness testing results confirm that the proposed observer achieves good performance on estimation accuracy, real time, and robustness.

17:00-17:20 ThE3.6

Acceleration Velocity Trajectory Optimization of Intelligent EVs Using Battery Life Model, pp. 308-312

Chu, Hong — Jilin Univ
Zheng, Qing — Jilin Univ
Guo, Lulu — Jilin Univ
Gao, Bingzhao — Jilin Univ

In this paper, taking an intelligent electric vehicle as the research object, mathematical models are firstly built for calculating the percentage of lithium-ion battery capacity loss and the internal resistance increase. Based on the model established, a control-oriented battery life model is derived using to calculate the battery capacity loss during an acceleration process. Then, a velocity trajectory optimization framework is presented to minimize the battery aging life for intelligent EVs during an acceleration process and the problem is solved by SQP algorithm. Finally, according to the simulation results, it can be concluded that the energy consumption per meter is 5.50kJ/m from 0 to 100km/h within 10s. The effect on battery capacity is much greater than that on battery internal resistance during the acceleration process.

ThE4 Meeting Room of Spring Dawn

Practical Combustion Control (Invited session)

Chair: Mizumoto, Ikuro — Kumamoto Univ
Co-Chair: Hikita, Takayuki — Mazda Motor Corp
Organizer: Yamasaki, Yudai — The Univ. of Tokyo
Organizer: Mizumoto, Ikuro — Kumamoto Univ

15:20-15:40 ThE4.1

Study on Model-Based Control for HCCI Engine (I), pp. 313-319

Hikita, Takayuki — Mazda Motor Corp
Mizuno, Saori — Mazda Motor Corp
Fujii, Takuma — Mazda Motor Corp
Yamasaki, Yudai — The Univ. of Tokyo

Hayashi, Takuya — The Univ. of Tokyo
Kaneko, Shigehiko — The Univ. of Tokyo

In order to realize stable and fuel-efficient operation with homogeneous charge compression ignition (HCCI) combustion, it is necessary to precisely control in-cylinder conditions such as gas temperature and oxygen concentration according to the target load set for each cycle. The HCCI combustion discussed in this study utilizes internal exhaust gas recirculation (EGR). For this type of combustion, the exhaust gas temperature and composition in the last cycle should be accurately estimated, and the internal EGR rate and the fuel injection quantity should be appropriately commanded to generate in-cylinder conditions that ensure combustion in the next cycle. To implement this effectively, the authors constructed a control-oriented model for the HCCI combustion which utilizes internal EGR with the negative valve overlap method, and developed a model-based feedforward controller based on this model. Firstly, the model-based feedforward controller was validated by simulations in which a change in the target load was given to the controller. Secondly, engine experiments were conducted to validate the controller in the same way. The results confirmed that the model-based feedforward controller was able to generate in-cylinder conditions suitable for the target load given to each cycle and thus realize stable HCCI combustion while following the target load.

15:40-16:00 ThE4.2

Knock Detection Using Multiple Indicators, pp. 320-325

Ängeby, Jakob — Sem Ab
Johnsson, Anders — Sem Ab
Hellström, Kristina — Sem Ab

Knock can be measured using in-cylinder pressure measurement. In series production, however, pressure sensors are rarely used due to cost and life time issues. Alternatives to the pressure sensor are vibration and ion sensors. However, robust knock detection using these sensors is a challenge and limits the overall engine performance and protection. By combining multiple knock indications, the performance of the overall knock detection can be improved. A classification approach is described that significantly improves the performance and robustness of knock detection. Also, the calibration is simplified, and the calibration effort reduced. A practical application on a HD natural gas fueled engine shows that the correct detection of knock given a fixed probability of false alarm is significantly improved.

16:00-16:20 ThE4.3

Lower Bound of Variance Minimization in Lean Combustion Control (I), pp. 326-330

Shen, Xun — Sophia Univ
Zhang, Yahui — Sophia Univ
Shen, Tielong — Sophia Univ

In this paper, the analysis on the performance of combustion variation feedback control is conducted based on the information theory. According to the theorem which calculates the lower boundary in variance minimization from the Gaussianity-Whiteness of the signal, the feedback control cannot reduce the error variance caused by white Gaussian disturbance. Then, as combustion variation control performance validation, the lower boundary in variance minimization under one certain lean combustion condition are calculated and the control performances of several controllers are compared to the lower boundary.

16:20-16:40 ThE4.4

Study on Variable Parameter Linear Active Disturbance Rejection Control for GDI Engine Common Rail Pressure (I), pp. 331-336

Du, Meng — Beijing Inst. of Tech
Zuo, Zhe — Beijing Inst. of Tech
Zhang, Fujun — Beijing Inst. of Tech
Lu, Yi — Beijing Inst. of Tech
Zheng, Pai — Beijing Inst. of Tech
Yao, Jianwei — Beijing Inst. of Tech

Gasoline Direct Injection(GDI) engines with Common Rail system can strongly improve the performance of the engine. In order to achieve the advantages promised by this technology, the rail pressure must satisfy the pressure requirement. In this work a method of Linear Active Disturbance Rejection Controller(LADRC) based on the rail pressure characteristics of the common rail system is proposed. To simplify the parameter tuning process, the Genetic Algorithm was used to optimize the controller. Focus on further improve the controller performance, the method of Variable Parameter LADRC(VPLADRC) is presented in this paper. In order to verify the effect of the controller, a simulation has been done based on the ideal model of common rail system. The simulation results confirm the effectiveness of VPLADRC. This method can satisfy the rail pressure control requirement. Compared with PID control, this method can further reduce the steady-state error and has greater optimization potential.

16:40-17:00 ThE4.5

Inlet NOx and NH3 Concentration Estimation for Diesel-Engine SCR Systems by Combining Data-Driven Model and Unbiased FIR Filter (I), pp. 337-341

Jiang, Kai — Beihang Univ
Hu, Chuan — McMaster Univ
Yan, Fengjun — McMaster Univ
Zhang, Hui — The Ohio State Univ

Selective catalytic reduction (SCR) systems have been widely used in diesel engine applications. In an SCR system, input NOx and NH3 concentration information are of critical importance for the urea dosage controller design and system fault detection. Generally, the NOx and NH3 concentration are obtained by physical sensors. However, the physical sensors do not only increase the cost of overall system, but also induce measurement delays. To deal with this issue, an input observer combining a data-driven model and an unbiased finite impulse response (FIR) filter is proposed. The structure of data-driven model is auto-regressive exogenous (ARX) model and partial least square (PLS) is utilized to identify the parameters in the ARX model. Nevertheless, fuzzy c-means (FCM) is also employed to partition the data and obtain multiple local linear models for describing the nonlinearities of the system. At last, an unbiased FIR filter is adopted to estimate the input NOx and NH3 concentration simultaneously due to its strong robustness against the noise. The comparisons between the unbiased FIR filter algorithm and Kalman filter algorithm are carried out in MATLAB/SIMULINK. The simulation results demonstrate that the performance of proposed estimator is outstanding.

17:00-17:20 ThE4.6

Combustion Phasing Modelling of Dual Fuel Engines, pp. 342-347

Sui, Wenbo — Illinois Inst. of Tech
Pulpeiro González, Jorge — Illinois Inst. of Tech
Hall, Carrie — Illinois Inst. of Tech

Dual fuel engines can achieve high efficiencies and low emissions but also can encounter high cylinder-to-cylinder variations on multi-cylinder engines. In order to avoid these variations, they require a more complex method for combustion phasing control such as model-based control. Since the combustion process in these engines is complex, typical models of this system are complex as well and there is a need for simpler, computationally efficient, control-oriented models of the dual fuel combustion process. In this paper, a mean-value combustion phasing model is designed. Combustion phasing is predicted using a knock integral model, burn duration model and a Wiebe function.

ThE5	The 2nd Meeting Room In North Zone
Driver Assistance and Vehicle Dynamics (Regular session)	
Chair: Xie, Hui	Tianjin Univ
Co-Chair: Ni, Jun	Beijing Inst. of Tech

15:20-15:40 ThE5.1

Study on Improvement of Adaptive Cruise Control Based on Model Control, pp. 348-352

Shang, Bingxu — China FAW Group Co., Ltd
Wang, Hongfeng — China FAW Group Co., Ltd
Chen, Zhixin — China FAW Group Co., Ltd
Liu, Yang — China FAW Group Co., Ltd
Han, Yanhui — China FAW Group Co., Ltd

A layered algorithm for Adaptive Cruise Control System based on real driving characteristic has been proposed in this paper. The upper layer which is a decision-making model is responsible for calculating a designed acceleration according to the driving environment and the driving characteristic which the cruise control applying with the PID control method, the follow control applying with the phase-map control method, and the curve control limiting the maximum longitudinal speed based on the road curvature. The lower layer which is longitudinal control model is focusing on transforming the designed acceleration into torque/deceleration and managing the vehicle execution system. The experimental results showed that, Adaptive cruise control system is proposed can be well simulate the characteristics of drivers, and be with good industrial applicability.

15:40-16:00 ThE5.2

A Robust Control Invariant Set Approach to Yaw Stability of Four-Wheel Drive Electric Vehicle, pp. 353-358

Jia, Fengjiao — Harbin Inst. of Tech
Liu, Zhiyuan — Harbin Inst. of Tech
Zhou, Hongliang — Harbin Inst. of Tech
Teng, Ting — Harbin Inst. of Tech

In this paper, a novel yaw stability control strategy for four-wheel drive electric vehicle under critical driving situations is presented. The motivation of this research is that oversteer occurs or yaw response performance is reduced when an inappropriate desired yaw rate is designed during the yaw rate tracking control. Although the bounded desired yaw rate is widely utilized to prevent oversteer in literatures, it is difficult to put forward the desired yaw rate which takes both yaw response and stability performance into account in practice. Considering that oversteer is caused by lateral forces saturation of rear wheels, this paper proposes a control strategy to constrain the lateral forces of rear wheels directly instead of bounding the desired yaw rate. The key of this work is that the state space consisting of yaw rate and side slip angle is firstly divided into two parts: saturated and unsaturated space of lateral forces of rear wheels. In the unsaturated space, the yaw rate tracking control is applied to enhance the yaw response performance. And In the saturated space, a robust invariant set yaw rate control is proposed to keep the tire slip angle of rear axle in a robust invariant set to constrain lateral forces of rear wheels. In this paper, the design approach of the robust invariant set control for yaw stability is discussed in detail. Simulation results show the effectiveness of the proposed method for enhancing yaw rate response performance and preventing lateral forces saturation of rear wheels.

16:00-16:20 ThE5.3

The Effects of an Eco-Driving Assistance System for a City Bus on Driving Style (I), pp. 359-364

Xiong, Shuo — Tianjin Univ
Xie, Hui — Tianjin Univ
Qiang, Tong — Tianjin Univ

Fuel consumption of a city bus is greatly influenced by driving style, and driving assistance systems (DAS) is a key technology to encourage driving style improvement. In the research reported here, we construct a real-time DAS for a city bus based on a decision tree algorithm. The DAS aims to reduce fuel consumption by encouraging three behaviors: reduced rates of acceleration, reduced depth of acceleration pedal and early upshifting through the gears. Using the proposed DAS, we establish a driver experiment platform with a driving simulator. Then, we design an experiment for 4 non-professional drivers with various driving experience to determine the effects of DAS on their driving style. The driving simulator experiment results show that all the drivers exhibited an observable change in acceleration pedal depth distribution, acceleration pedal positive gradient distribution, and shift timing. These findings indicated that through the real-time guidance on the manipulation of the accelerator pedal position and gear, the drivers could obey the devices from DAS to a certain extent, so the Eco-Driving device can help drivers change their driving style.

16:20-16:40 ThE5.4

Eco-Driving at Signalized Intersections Based on Driving Behavior Self-Learning (I), pp. 365-370

Lu, Honglei — Tianjin Univ
Chen, Tao — Tianjin Univ
Xie, Hui — Tianjin Univ
Song, Kang — Tianjin Univ

"Human-vehicle-road" collaborative optimization is an important issue in current research. And the topic of how to build an appropriate driver model integrating future traffic information has not been totally solved. In this paper, Gaussian Mixture Model (GMM) was adopted to learn different driving modes. And a linear acceleration model, was identified by least square method which was weighted by probability density of the GMM. Therefore, the most energy-saving acceleration model could be evaluated by a comprehensive score. Based on this model, the planning and control of driving speed in single traffic light scene was explored. Simulation results show that the planning strategy proposed in this paper can save fuel up to 15.81% compared with the aggressive driver; and 14.54% reduced compared with the fixed speed planning algorithm based on vehicle to infrastructure (V2I) communication, with traffic light restriction satisfied.

16:40-17:00 ThE5.5

A Drive-By-Wire Mother-Child UGV and Performance Evaluation in Remote Control Mode (I), pp. 371-375

Ni, Jun — Beijing Inst. of Tech
Hu, JiBin — Beijing Inst. of Tech
Zhao, Yue — Beijing Inst. of Tech
Pan, Bo — Beijing Inst. of Tech
Li, Yunxiao — Beijing Inst. of Tech

This paper presents a mother-child type X-by-wire Unmanned Ground Vehicle (UGV), which is called Unmanned Ground Carrier (UGC). The UGC has civilian and military versions, which can carry several rotorcrafts and robot to collaboratively conduct the missions. The mother vehicle of the UGC is fully X-by-wire, which applies pure electric powered, in-wheel motor driven and independent steer techniques to improve the performance to negotiate both urban and field environments. The chassis dynamics control techniques of the UGC are summarized in this paper. In addition, the experiments results are provided to evaluate the performance of the UGC.

17:00-17:20 ThE5.6

Study on the Slip Rate of CVT in Un-Steady States, pp. 376-381

Zhu, Hong-bo — Jilin Univ

Zhang, You-kun — Jilin Univ
Wang, Yong-cong — Jilin Univ
Guo, Yue-han — Jilin Univ

Aiming at the slip rate of CVT, the relationship between the actual optimal slip rate and the theoretical optimal slip rate is analyzed. The recognition method of vehicle driving cycle is established, the correction coefficient of slip rate in different driving condition can be determined and then the slip rate will be controlled to the theoretical optimal value. Based on the simulation model of the vehicle with CVT and analysis result of Co-simulation of Simulink and AMESim, the clamping force control method in un-steady drive states is proposed and a comparison with the traditional clamping force control method is made. And then Experimental results show that these method increases slip rate stability, improves the efficiency of the CVT, and verifies the feasibility of the clamping force control method.

ThE6 — The 3rd Meeting Room In South Zone

Engine After-Treatment Control and Diagnosis (Invited session)

Chair: Guardiola, Carlos — Univ. Pol. De Valencia
Co-Chair: Dahl, Johan — Powertrain Engineering, Volvo Group Trucks Tech
Organizer: Guardiola, Carlos — Univ. Pol. De Valencia
Organizer: Pla, Benjamín — Univ. Pol. De Valencia

15:20-15:40 — ThE6.1

Model Predictive Control of a Diesel Engine with Turbo Compound and Exhaust After-Treatment Constraints, pp. 382-387

Dahl, Johan — Powertrain Engineering, Volvo Group Trucks Tech
Wassen, Henrik — Volvo Group Truck Tech. Powertrain
Santin, Ondrej — Czech Tech. Univ
Herceg, Martin — Honeywell, Spol. S.r.o
Lansky, Lukas — Honeywell
Pachner, Daniel — Honeywell
Pekar, Jaroslav — Honeywell

In this work we consider air path control of a Volvo Heavy Duty 13L Diesel engine equipped with three air path actuators Exhaust Gas Recirculation Valve (EGV), Intake Throttle Valve (ITV), turbocharger Wastegate (WG), and a Turbo Compound (TC). The purpose of the TC device is to recover the waste heat energy to improve fuel efficiency. Thus, the motivation is to control the air path system and in particular the exhaust energy to achieve satisfaction of the Exhaust After-Treatment System (EATS) requirements and assess the fuel economy. For this purpose a commercially available industrial tool for Model Predictive Control (MPC) has been applied. The designed controller is integrated in a production Engine Electrical Control Unit (EECU) and tests are performed both in engine test bench and on-road. The results show that by coordination of the air path actuators utilizing advanced MPC framework it leads to improvements in the exhaust energy conversion which was measured by fuel reduction of 0.3% with maintained NOx levels in a World-Harmonized Transient Cycle (WHTC) compared to a Proportional Integral Derivative (PID) control scheme. The designed MPC controller reached mass production maturity level and had a similar margin to the EU6 emission regulation as the compared PID control scheme.

15:40-16:00 — ThE6.2

Oxygen Catalyst Depletion Strategy Based on TWC Control-Oriented Modelling (I), pp. 388-394

Desantes Fernández, José — Univ. Pol. De València
María
Guardiola, Carlos — Univ. Pol. De Valencia
Pla, Benjamín — Univ. Pol. De Valencia
Real Minuesa, Marcelo — CMT-Motores Térmicos, Univ. Pol. De València

This paper presents and experimentally evaluates different model-based O2 depletion strategies for the TWC during a tip-in after a fuel cut-off. The objective is to find an optimal depletion strategy in the sense of minimum fuel consumption while keeping NOx emissions during the transient below certain limit. To do that, in the present paper, a control oriented model of the TWC is combined with a Direct Method to solve the corresponding Optimal Control Problem. The analysis of the obtained results allows to design model-based control strategies whose performance is experimentally assessed. In particular, the results obtained show the tradeoff between fuel consumption and NOx emissions during the analysed transient.

16:00-16:20 — ThE6.3

Calibration of a Mass Balance Based Soot Load Estimation Model for Diesel Particulate Filter, pp. 395-398

Huang, Tiexiong — Chengdu WIT Electronic Fuel System Co., Ltd
Zhu, Yuanxian — Chengdu WIT Electronic Fuel System Co., Ltd
Ran, Yong — Chengdu WIT Electronic Fuel System Co., Ltd
Zhang, Mingchao — Chengdu WIT Electronic Fuel System Co., Ltd
Jing, Si — Chengdu WIT Electronic Fuel System Co., Ltd

To accurately estimate the amount of soot in the diesel particulate filters (DPFs) is critical to maintain DPF integrity while minimizing the fuel penalty. A mass balance based soot load estimation model is developed by use of the engine-out soot emission and DPF passive regeneration characteristics. Calibration mapping and the mapping result are described and discussed. Experimental validation is carried out in both engine test cell and vehicle road tests. Results show that after calibration mapping in a systematic way, the proposed mass balance based model has achieved an accuracy of +/-1g/L, which indicates a considerable potential to contribute to the DPF applications and management.

16:20-16:40 — ThE6.4

DPF Soot Loading Estimation Strategy Based on Pressure Difference, pp. 399-401

Ran, Yong — Chengdu WIT Electronic Fuel System Co., Ltd
Huang, Tiexiong — Chengdu WIT Electronic Fuel System Co., Ltd
Zhang, Mingchao — Chengdu WIT Electronic Fuel System Co., Ltd
Jing, Si — Chengdu WIT Electronic Fuel System Co., Ltd
Zhu, Yuanxian — Chengdu WIT Electronic Fuel System Co., Ltd

The China V emission standard for light duty vehicles, starting to be effective from January 1, 2018, is the first time to set particulate number (PN) emission limits. This necessitates diesel particulate filters (DPFs) to be equipped for diesel powered pick-up trucks. A DPF soot load estimation model based on the DPF pressure drop is established to support the regeneration time selection and DPF applications and management. The accuracy of the model is validated through the engine dynamometer testing and on-vehicle road tests.

16:40-17:00 — ThE6.5

An OBD Strategy to Estimate SCR Ageing and Detect Urea Injection Faults (I), pp. 402-409

Mora, Javier	Univ. Pol. De València
Willems, Frank	Eindhoven Univ. of Tech
Seykens, Xander	TNO
Guardiola, Carlos	Univ. Pol. De Valencia

The most recent regulation for diesel engines with regards to NOx emissions and SCR systems considers stringent OBD requirements, for which the implementation of a downstream NOx sensor is mandatory and an NH3 sensor can be added to determine NH3 and NOx concentrations. In this paper, an observer of the ageing state is developed considering NO, NO2 and NH3 concentrations, the surface coverage ratio and the ammonia storage capacity as states. The observer is based on an extended Kalman filter. Accuracy and convergence time are presented for the observer validation in a dynamic WHTC at warm starting conditions. As the ageing state estimation is based on the residual between a model and measurements, an additional indicator avoids associating an error inherent of urea injection faults to ageing. The performance of this indicator is independent from the ageing state of the SCR. The highly detailed, physics-based 1D SIMCAT model is used as the SCR plant for the ageing estimation and as the model to track the urea injected quality. Then, a control-oriented model is also used in simulation to allow the state-space representation required for the observer. Accuracy of both models is argued, showing the limitations and advantages of the control-oriented model.

17:00-17:20 ThE6.6

A New Grid Map Construction Method for Autonomous Vehicles, pp. 410-415

Wang, Xiantao	Beijing Inst. of Tech
Wang, Weida	Beijing Inst. of Tech
Yin, Xufeng	Beijing Inst. of Tech
Xiang, Changle	Beijing Inst. of Tech
Zhang, Yuanbo	Beijing Inst. of Tech

Grids map provide a simple but accurate way of understanding surroundings which means they could play a vital role in methods of environment perception. A new grid map construction approach to environment perception aimed at unmanned ground vehicles is proposed in this paper. First, the pose of the raw point cloud from the LiDAR system (Velodyne HDL-32E) is aligned by introducing data from IMU. Then, the RANSAC algorithm is utilized to remove the ground part of the point cloud and a grid map is established using octrees. The probability of occupancy grid map is updated based on data fusion with Bayesian inference and the Dezert–Smarandache theory combination rule. Finally, a cluster analysis is performed and moving objects are detected on the grid map, in order to facilitate obstacle detection and selection of the accessible road area. Experimental results show that the resulting grid map based on octrees and data fusion can be reliably applied to vehicle perception and that the approach is highly practicable.

Technical Program for Friday September 21, 2018

FrA2	Convention Room of Pines
Hybrid and Electric Vehicles III (Regular session)	
Chair: Jiao, Xiaohong	Yanshan Univ
Co-Chair: Zhang, Yahui	Sophia Univ

13:00-13:20 FrA2.1

Applying Forward Dynamic Programming to Combined Energy and Thermal Management Optimization of Hybrid Electric Vehicles, pp. 416-422

Engbroks, Lukas	Daimler AG
Goerke, Daniel	Daimler AG
Schmiedler, Stefan	Daimler AG
Strenkert, Jochen	Daimler AG
Geringer, Bernhard	Vienna Univ. of Tech

The efficiency of internal combustion engines (ICEs) is well-known to be low at cold starting conditions. Additionally, the energy demand for passenger compartment heating is substantial and either provided by an electrical auxiliary heater or in terms of the engine waste heat. Plug-in hybrid electric vehicles (PHEVs) are prone to suffer from extended warm-up periods due to increased engine off periods as compared to conventional vehicles. Energy management strategies (EMSs) however allow for warm-up applications independent of the drive torque request. Optimal control theory serves as benchmark for EMS, offering a variety of numerical methods. This paper focuses on forward dynamic programming (FDP) accounting for causal system dynamics such as engine temperature. Results confirm, that even though the fuel saving potential of the engine warm-up is significant, it is hardly influenced by means of the EMS. A second implementation variant is proposed to counteract the curse of dimensionality. The presented approach not entirely achieves global optimality, yet yields results close to optimum within reasonable computational times. As opposed to the reference, the proposed method allows accounting for a variety of causal system dynamics leading towards an EMS more close to reality.

13:20-13:40 FrA2.2

Energy Recovery and Reuse Management for Fuel-Electric-Hydraulic Hybrid Powertrain of a Construction Vehicle, pp. 423-426

Wang, Zhong	Yanshan Univ
Jiao, Xiaohong	Yanshan Univ
Pu, Zesong	Yanshan Univ
Han, Lu	Yanshan Univ

Aiming at the frequent start-stop of a straight-manipulator aerial platform vehicle for sandblasting and spray painting hull, a hydraulic energy recovery and reuse unit consisting of accumulator and pump/motor is connected in parallel on the original series hybrid system. The main purpose of the modified hybrid powertrain is to exploit the operational characteristics of the hydraulic pump/motor to recover the kinetic energy during vehicle braking. And while, during the climbing and acceleration process, the stored energy in accumulator is quickly released to meet the intermittent and high power requirements of the system. Firstly, the fuel-electric-hydraulic hybrid power system is presented for an actual aerial platform vehicle. And then a logical control strategy of the energy management is designed according to vehicle driving condition. The simulation comparison result is given between the fuel-electric-hydraulic hybrid system and the original series hybrid system.

13:40-14:00 FrA2.3

Simulation and Analysis of Energy Consumption for Plug-In Hybrid Electric Vehicles Based on Driving Cycles, pp. 427-432

Lei, Zhenzhen	Chongqing Univ
Sun, Dongye	Chongqing Univ
Liu, Yonggang	Chongqing Univ
Li, Jie	Chongqing Univ
Zhao, Pan	Chongqing Univ

Abstract: The energy consumption of plug-in hybrid electric vehicles (PHEV) is influenced by driving cycles. In this paper, the influence of driving cycles has been analyzed for the PHEV energy consumption, which can provide a theoretical basis for the energy management strategy development. The K-means clustering method is used to divide driving cycles into different patterns. The energy consumption mathematical models of the PHEV powertrain are built based on the efficiency models of powertrain system. Then, the simulation models of energy consumption for PHEV are built based on MATLAB/Simulink software, and the simulation has been conducted using the CD-CS control strategy. Finally, the influence of driving cycles on energy consumption is obtained. The results show that taking full use of electrical energy is the more important to improve energy efficiency for PHEV, comparing with the traditional control of PHEV is only to enhance engine operating efficiency.

14:00-14:20 FrA2.4

Optimization of Power Hybrid Control Strategy Parameters of Hybrid Bus, pp. 433-439

Peng, Meichun	Guangdong Univ. of Tech
Li, Jilong	Guangdong Univ. of Tech
Yue, Zheng	Guangdong Univ. of Tech

It was studied the optimization of power control strategy parameters for reduction of gas consumption of a series-parallel LNG-electricity hybrid bus. The control parameters included the up and low limit value of SOC of super-capacitor, limited speed of vehicle in pure electric model, shutoff torque coefficient of engine and charging coefficient. The optimization was carried out by joint simulation by coupling the performance simulation model of vehicle and the optimization model of control parameters. It was applied DOE of Latin hypercube in simulation test, and set up relationship between control parameters with gas consumption by approximate model of quadratic response. The optimal value of control parameters was gotten with Multi-island genetic algorithm, and the gas consumption of bus was reduced effectively.

14:20-14:40 FrA2.5

Electromagnetic Parameters Matching of Permanent Magnet Synchronous Motor for Hybrid Electric Vehicles, pp. 440-447

Wang, Weihua	Jilin Univ
Fu, Rong	Jilin Univ
Fan, Yongkai	Jilin Univ

As one of the significant power sources to characterize the driving performance of hybrid electric vehicles (HEV), the motor parameter matching is an important issue. A simple method is proposed to calculate the electromagnetic parameters of motor considering the influence of field-weakening ratio and saliency ratio on the motor external characteristic. Through analyzing the influence of the saliency ratio and the field-weakening ratio on the external characteristics, the candidate ranges of the saliency ratio and the field-weakening ratio are provided. The result indicates that the actual range of field-weakening ratio is 1.09-1.15 when the saliency ratio is 2.5 and the value of the saliency ratio is 2.00-2.73. Then the electromagnetic parameters of PMSM can be acquired, which can meet the power demand of HEV. The electromagnetic parameters are related with the structure parameters to some extent, so the paper can provide references for the structure parameters design of PMSM in HEV.

14:40-15:00 FrA2.6

Mutual Inductance Estimation of Wireless Power Transmission System by the Least Squares Method, pp. 448-453

Song, Jian — Zhejiang Univ
Liu, Zhitao — Zhejiang Univ
Su, Hongye — Zhejiang Univ

In this paper, least square method is used to identify the mutual inductance in the dynamic wireless power transfer system (WPT). The mutual inductance at different relative distance between the transmitter coil and the receiver coil is identified, and its function is obtained by curve fitting. The mathematical model of the WPT circuit is given, PLECX is used to analyze the its property, and ANSYS is applied to analyze the magnetic field strength and magnetic induction intensity around a designed coil. Finally, the experimental and simulation results are given to prove the performance of the mutual inductance identification.

15:00-15:20 FrA2.7

EVT Logistics Vehicle Cost Recovery Cycle and Economic Analysis, pp. 454-461

Zeng, Xiaohua — Jilin Univ
Li, Hongcheng — Jilin Univ
Song, Dafeng — Jilin Univ. State Key Lab. of Automotive Simulation
Yang, Nannan — Jilin Univ. State Key Lab. of Automotive Simulation
Wang, Zhenwei — Jilin Univ

Abstract: Hybrid vehicles are favored by the market because of their good economic. Therefore, the cycle of cost recovery and its economy have become one of the most concerned issues in the development process. This paper analyzes the economic impact factors of logistics vehicles using electronic continuously variable transmission (EVT) hybrid power system. At the same time, the cost and the cost recovery cycle under different conditions were estimated and analyzed. Finally, the fuel economy of traditional vehicles, EVT logistics vehicle with electrified engine accessories and without electrified engine accessories was compared and analyzed. This paper provides a method for calculating the cost recovery cycle of hybrid vehicles. At the same time, it provides a reference for the development and design of the system from the perspective of obtaining better economical efficiency.

FrA3 — The 2nd Meeting Room In South Zone

Engine and Powertrain Control III (Invited session)

Chair: Kang, Mingxin — Northeastern Univ
Co-Chair: Gao, Jinwu — Jilin Univ
Organizer: Kang, Mingxin — Northeastern Univ
Organizer: Gao, Jinwu — Jilin Univ

13:00-13:20 FrA3.1

Adaptive Lean Air-Fuel Ratio Control and Analysis of Commercial Gasoline Engines (I), pp. 462-467

Khajorntraidet, Chanyut — King Mongkut's Univ. of Tech. North Bangkok
Shen, Tielong — Sophia Univ

This paper presents an adaptive lean air-fuel ratio control and analysis of commercial gasoline engines. There are two main parts in this research which are lean air-fuel ratio control and investigation of lean operation effects. Firstly, the adaptive control strategy is applied for the amount of fuel injection control while the spark advance is regulated for maintaining the engine torque by a calibrated look-up table. Secondly, the values of the location of peak pressure (LPP) and the location of 50% of the mass fraction burned (CA50) are used as the main indicators for the lean combustion analysis. Subsequently, the net indicated mean effective pressure (IMEPn) is considered for the engine performance evaluation. The experimental results show that the applied control strategy has high performance for the lean operation mode of the commercial gasoline engine. In addition, the combustion parameters and IMEPn investigation can be used to analyze the effects of lean operation mode on the engine.

13:20-13:40 FrA3.2

Chattering-Free Sliding Mode Control for Diesel Engine Air Path System with Actuator Faults (I), pp. 468-473

Zhang, Jian — Harbin Engineering Univ
Liu, Long — Harbin Engineering Univ
Li, Xuemin — Harbin Engineering Univ
Li, Wenhui — Harbin Engineering Univ

In this paper, a chattering-free sliding mode control law is constructed for the diesel engine air path system with consideration of partial loss of actuator effectiveness and additive fault. Firstly, sliding mode method and adaptive technique are employed to develop a fault-tolerant controller. With the adaptation update law, there is no requirement of the priori knowledge of the upper bounds of the actuator faults. Then, to attenuate the chattering behavior and improve system performance, the boundary layer is introduced to modify the sliding mode control method. Rigorous theoretical analysis is presented based on Lyapunov stability theory, which demonstrates that the system trajectories converge to a small neighborhood around the origin. Finally, numerical simulation results are carried out to show the effectiveness and validness of the proposed algorithms.

13:40-14:00 FrA3.3

Parameter Identication and Nonlinear Compensation Control Design of Electronic Throttle (I), pp. 474-480

Feng, Kai — Jilin Univ
Sun, Boqi — Jilin Univ
Hu, Yunfeng — Jilin Univ
Gao, Jinwu — Jilin Univ

Precise electronic throttle control is a basic problem of engine control. This paper identifies the model parameters based on input PWM, throttle output angle and angular velocity. But the angular velocity can not be measured directly. Therefore, the kalman filter is applied to calculate the angular velocity. A hybrid optimization algorithm is used to search the parameters of throttle model which minimizes the errors between model and real throttle output angle and angular velocity. The controller is designed based on identified parameters and triple-step nonlinear control design. Experimental results indicate the effectiveness of the identified parameters and the controller.

14:00-14:20 FrA3.4

Modeling and Control of Gasoline PPC Engine Approaching High Efficiency with Constraints (I), pp. 481-486

Yang, Tianhao — Dalian Univ. of Tech
Yin, Lianhao — Lund Univ
Long, Wuqiang — Dalian Univ. of Tech
Tunestal, Per — Lund Univ. Faculty of Engineering
Tian, Hua — Dalian Univ. of Tech

Gasoline-fueled Partially Premixed Combustion is an advanced combustion concept approaching high efficiency as well as low emissions. The most challenging task on controlling a gasoline PPC engine is to regulate the maximum pressure rise rate to reduce engine noise and durability problem. A trade-off relationship between pressure rise rate and soot emissions is observed as a function of pilot injection event. In this paper, a control-oriented

model is developed to predict in-cylinder pressure and engine outputs through fuel injection events. Thereafter, two controllers structured with PI and MPC are designed and evaluated separately. Simulation results show that, both controllers satisfy the objective of achieving desired engine load and combustion phasing, with the constraints of pressure rise rate and soot emissions simultaneously. MPC controller produces a smoother transient move with less overshoot, comparing with PI controller with a fast response.

14:20-14:40 FrA3.5

Control-Oriented Cyclic Modeling Method for Spark Ignition Engines (I), pp. 487-492

Kang, Mingxin — Northeastern Univ
Sata, Kota — TOYOTA MOTOR Corp
Matsunaga, Akio — Toyota Motor Corp

Automotive engine is a sophisticated dynamical control system involving both continuous-time dynamic behavior and event-based cyclic state transition. To grasp the engine dynamics accurately, this paper proposes a hybrid model structure for automotive gasoline engines that not only consists of the continuous air path model, actuator response model, but also includes the cyclic residual gas mass model and combustion process model. The proposed model adopts an extended Kalman filter to on-line estimate the cyclic state and it has the potential to be applied for the real-time optimal control design to improve the transient control performance. The precision of the model has been evaluated by comparing with the measurement data and the validation results demonstrate the satisfactory model matching behavior.

14:40-15:00 FrA3.6

Look Ahead Based Supervisory Control of a Light Duty Diesel Engine, pp. 493-498

Velmurugan, Dhinesh — Volvo Car Corp
Lundberg, Daniel — Volvo Cars
McKelvey, Tomas — Chalmers Univ. of Tech

With recent developments in autonomous cars, route based optimisation is closer to reality. Penetration of such connected cars technology provides potential for optimisation of fuel consumption. In this paper, look ahead prediction is used along with lumped parameter based models to develop a supervisory controller for a light duty diesel engine. A supervisory interface proposed in earlier works for a light duty diesel engine with LNT-SCR aftertreatment system is used. The supervisory controller is designed with the objective of non-interference of local controllers. However, the ability to influence the subsystem with a system objective is maintained. The look ahead prediction comprises of vehicle speed and load trajectory. A set of discrete control actions are evaluated for the complete powertrain to determine the optimal action with respect to equivalent fuel consumption. The use of the simple models along with discrete control actions has low computational effort. After a full factorial simulation of the discrete actions carried out on-line, the optimal supervisory control action is chosen by selecting the action with least fuel consumption. The simulation results utilising the proposed controller is analysed for fuel equivalent consumption saving potential.

15:00-15:20 FrA3.7

Supervisory Control for Real-Driving Emission Compliance of Heavy-Duty Vehicles, pp. 499-505

Karim, Mohammed Razaul — Chalmers Univ. of Tech
Egardt, Bo S. — Chalmers Univ. of Tech
Murgovski, Nikolce — Chalmers Univ. of Tech
Gelso, Esteban R. — Volvo Group Trucks Tech

This paper presents an economic nonlinear MPC based strategy for integrated control of the engine and the exhaust aftertreatment system (EATS) of a heavy-duty powertrain. The objectives of this control strategy are to improve the fuel economy while fulfilling real-driving emission legislation based on work-based-window, as stipulated in the Euro VI emission legislation for heavy-duty vehicles. The strategy is evaluated using a high-fidelity simulation platform including a validated GT-POWER model of a 13L turbo compound diesel engine and a first principles model of an EATS. Simulation results show that the strategy always fulfills the real-driving emission legislation.

FrA4 Meeting Room of Spring Dawn

Electronic Architectures and Control (Regular session)

Chair: Rolle, Bernhard — Univ. of Stuttgart
Co-Chair: Gao, Jinwu — Jilin Univ

13:00-13:20 FrA4.1

Research on Active Control System of Vehicle Noise Caused by Pavement Excitation, pp. 506-511

Li, Hui — Changchun Univ. of Tech. Automotive Engineering Res
Zhang, Shuo — Changchun Univ. of Tech

In order to reduce the interior noise caused by road excitation,the finite element analysis method is used to analyze the modal of the interior space, and then get the frequency response curve of the corresponding nodes in the car ear.Through the establishment of an adaptive neural network noise active control system simulink model, the simulation experiment is carried out.The experimental results show that the active control system of neural network noise control in the 0 to 50 frequency band has good noise reduction effect and the average noise reduction is 4.3 . At 86 , the maximum noise reduction is 9.8 ,and the system can control the low frequency noise produced under the excitation of the road.

13:20-13:40 FrA4.2

Fuzzy Control of Electric Vehicles for Understeer Prevention, pp. 512-517

Zhang, Qian — Harbin Inst. of Tech
Liu, Zhiyuan — Harbin Inst. of Tech

In understeer manoeuver, lateral tire forces of front tires are saturated. Thus, the widely-used linear tire model in yaw stability control is no longer suitable for understeer prevention. Moreover, the longitudinal motion is neglected and only the lateral and yaw motions are taken into account in the dynamic model. To overcome these shortcomings, a new tire model and a control strategy are proposed in this paper. First, a piecewise affine (PWA) model is established. Next, a 3DoF dynamic model is obtained based on the new tire model. Finally, a fuzzy yaw stability controller is designed based on the T-S fuzzy model representing the above dynamic model. Simulation results show that the nonlinear lateral force can be approximated by the PWA tire model accurately, and the control strategy is efficient for understeer prevention.

13:40-14:00 FrA4.3

Analytical Voltage-Source Inverter Current and Conduction Loss Models for EV Power Train Simulations, pp. 518-523

Rolle, Bernhard — Univ. of Stuttgart
Sawodny, Oliver — Univ. of Stuttgart

This study introduces a novel approach to derive analytical expressions of modulated semi-conductor current waveforms, which are used to develop accurate and numerically efficient average value models of the transistor current, diode current and conduction loss in VSI-drives. The approach is based on a double Fourier integral analysis of semi-conductor switching signals. Compared to previous studies, the proposed models show improved accuracy. Furthermore, the presented framework is readily generalized to evaluate the performance of practical, carrier-based PWM strategies within detailed EV power train simulations.

14:00-14:20 FrA4.4

Predictive Velocity Control in a Hilly Terrain Over a Long Look-Ahead Horizon, pp. 524-531

Hamednia, Ahad — Chalmers Univ. of Tech
Murgovski, Nikolce — Chalmers Univ. of Tech
Fredriksson, Jonas — Chalmers Univ. of Tech

This paper presents a computationally efficient velocity control of vehicles driving in a possibly hilly terrain and over long look-ahead horizons that may stretch to hundreds of kilometers. The controller decouples gear scheduling into an onine optimization problem, from the remaining optimization problem that governs two real-valued states. One of the states, the travel time, is adjoined to the objective by applying the necessary optimality conditions, which results into an online optimization problem that has kinetic energy as the single state. Finally an inner approximation is proposed for the online problem to obtain a quadratic program that can be solved efficiently. The efficiency of the proposed controller is shown for dierent horizon lengths.

14:20-14:40 FrA4.5

Oxygen Excess Ratio Controller Design of PEM Fuel Cell, pp. 532-537

Li, Meng — Jilin Univ
Lu, Jiahao — Jilin Univ
Hu, Yunfeng — Jilin Univ
Gao, Jinwu — Jilin Univ

The work of this paper focuses on oxygen excess ratio control, for the oxygen excess ratio has a great influence on the performance of the proton exchange membrane (PEM) fuel cell. To model dynamics of air supply system and oxygen excess ratio, a validated three-order model is used for controller design. Because the pressure of the cathode is unmeasurable in the actual system, a state observer is designed to observe the cathode pressure based on the third-order model. A controller combining with feedforward control and feedback control based on LQR method and map that can output the equilibrium state, feedforward control signal and feedback gain calculated off-line at different equilibrium points through the input of the expected oxygen excess ratio and load current is then designed. At last, oxygen excess ratio control strategy under different working conditions is realized and the simulation results verify the effectiveness of the proposed controller.

14:40-15:00 FrA4.6

Lagrangian Modeling and Passivity Based Control of Induction Motors for Electric Vehicles, pp. 538-542

Pei, Wenhui — Shandong Jiaotong Univ

In this paper, the Lagrangian Model of the induction motor considering iron losses is proposed based on it's mathematical model in a synchronously rotating frame. First, the induction motors modeled in the dq reference frame are first shown to be Euler-Lagrange (EL) systems, and the parameters are explicitly identified. Based on the proposed EL model, passivity-based controllers are then synthesized using the techniques of energy shaping and damping injection.This method ensures the global stability of the system. The simulation validates the efficiency of the control scheme.

15:00-15:20 FrA4.7

Stochastic Speed Regulation of Eddy Current Retarder, pp. 543-548

Yang, Jun — Shandong Jiaotong Univ
Yi, Fengyan — Shandong Jiaotong Univ
Wang, Jinbo — Shandong Jiaotong Univ

The problem of stochastic speed regulation of the eddy current retarder considering the inaccuracy of the control of the braking torque is researched in this paper. An stochastic speed regulator is designed based on the dynamic model of the eddy current retarder, for the purpose of vehicle speed regulation. The validation of the proposed stochastic regulator is given by the numerical simulation from three folds. Firstly, the simulation results of the road slope is constant value show that the vehicle speed can be regulated to a neighbourhood of its desired value, and the temperature of the rotating disk can be regulated to its equilibrium value. Secondly, the validation of the proposed controller when the road slope is jumped from one degree to other one is given. Finally, the affection of the design parameter to the control performance is discussed, from which we can obtain the relationship between the control performance and the control design parameter.

FrA5 The 2nd Meeting Room In North Zone

Diesel Engine Combustion and Air-Path System Control (Invited session)

Chair: Yamasaki, Yudai — The Univ. of Tokyo
Co-Chair: Hirata, Mitsuo — Utsunomiya Univ
Organizer: Yamasaki, Yudai — The Univ. of Tokyo
Organizer: Hirata, Mitsuo — Utsunomiya Univ

13:00-13:20 FrA5.1

Adaptive Output Feedback Control System Design with Adaptive PFC for Combustion Control of Diesel Engine (I), pp. 549-554

Fujii, Seiya — Kumamoto Univ
Uchida, Satoshi — Kumamoto Univ
Mizumoto, Ikuro — Kumamoto Univ

This paper deals with a combustion control system design problem of diesel engines. We propose an adaptive output feedback control system design scheme with an adaptive parallel feedforward compensator (PFC) for diesel engines with triple fuel injections. In order to guarantee the stability of the designed adaptive control system, a PFC is introduced and adaptively adjusted for maintaining the almost strictly positive real (ASPR) property of the resulting augmented system. The SISO control system is designed by considering main injection timing as the control input and peal pressure timing as the output. The effectiveness of the proposed method is confirmed through numerical simulations.

13:20-13:40 FrA5.2

Diesel Engine Combustion Control Based on Cerebellar Model Articulation Controller (CMAC) in Feedback Error Learning (I), pp. 555-560

Zhang, Xinyu — Keio Univ
Eguchi, Makoto — Keio Univ
Ohmori, Hiromitsu — Keio Univ

The trend started in 1997 with the introduction of common rail injection and after some protocols set new targets for overall CO2 emissions. As the diesel engine emits less CO2 than its gasoline counterpart, it kept conquering more and more market shares. Conventional diesel engine control design is mainly based on the maps techniques which required too much time, money and human resources under the number of experiments under various environmental conditions. This makes increasing system complexity. In our authors group, we have proposed that the control structure has the feedback error learning, two-degree-of-freedom controller configuration, with advanced neural networks (NNs) as the feedforward controller along the model-based control method. On the other hand, a cerebellar model articulation controller (CMAC) is a non-fully connected perceptron like associative memory network with overlapping receptive fields, which is used to resolve problems that involve rapid growth and the learning difficulty. Then CMACs have the advantages of good generalization

capability, fast learning ability, and simple computation. To our best knowledge, this is new introduce the cerebellar model articulation controller (CMAC) for the control diesel engine combustion control. The effectiveness of the proposed method will be confirmed through numerical simulations based on the Tokyo University diesel engine model with triple fuel injections.

13:40-14:00 FrA5.3

Model-Based Control System for Air Path and Premixed Combustion of Diesel Engine (I), pp. 561-567

Takahashi, Motoki — The Univ. of Tokyo
Yamasaki, Yudai — The Univ. of Tokyo
Kaneko, Shigehiko — The Univ. of Tokyo
Koizumi, Jun — Utsunomiya Univ
Hayashi, Tomofumi — Utsunomiya Univ
Hirata, Mitsuo — Utsunomiya Univ

Premixed charge compression ignition (PCCI) combustion has a potential to achieve the low emission level while the thermal efficiency remains high. It requires more precise combustion control due to the low robustness of the premixed combustion. In this study, a model-based control system for both air path system and combustion is developed for realizing the ideal PCCI combustion in future. For the air path system control, a feedback (FB) controller based on H_∞ control theory is used. In this controller, the nonlinearity of the plant is considered as the perturbation and robustness is ensured by H_∞ control. For the combustion control, a feedforward (FF) controller is designed as an inverse model of a discretized combustion model. In this controller, the inverse model is updated cycle by cycle on-board to consider the variation of combustion characteristics depending on operation condition. The performance of the overall control system including both controllers is evaluated by the reference following test under the transient mode operation in both the simulation and the experiment for PCCI-like combustion with advanced fuel injection timing. The control system showed good tracking performance both in air path and combustion systems and the availability of the model-based control system is shown.

14:00-14:20 FrA5.4

An Application of C/GMRES Model Predictive Control to a Diesel Engine Air Path System (I), pp. 568-573

Nakada, Hayato — Toyota Motor Corp
Martin, Peter — Ricardo UK
Wijesinghe, Anuradha — Ricardo UK Ltd
Shirai, Hayato — Toyota Motor Corp
Matsunaga, Akio — Toyota Motor Corp
Tominaga, Hiroyuki — Toyota Motor Corp

This paper considers an application of a C/GMRES-based model predictive control (MPC) method to a diesel engine air path system. The plant model is derived based on the physical first principle to explicitly take account of plant nonlinearities. Since the plant has unmeasurable states, we employ an extended Kalman filter to estimate them. Then we design a C/GMRES-MPC algorithm and apply it to a real engine. We demonstrate the effectiveness of the present method by showing experimental results.

14:20-14:40 FrA5.5

Two-Degree-Of-Freedom H-Infinity Control of Diesel Engine Air Path System with Nonlinear Feedforward Controller (I), pp. 574-580

Hirata, Mitsuo — Utsunomiya Univ
Koizumi, Jun — Utsunomiya Univ
Hayashi, Tomofumi — Utsunomiya Univ
Takahashi, Motoki — The Univ. of Tokyo
Yamasaki, Yudai — The Univ. of Tokyo
Kaneko, Shigehiko — The Univ. of Tokyo

In this research, we developed a two-degree-of-freedom control system for a Diesel engine air path system. First, a physical air path model of the Diesel engine was developed. Then, a feedforward controller was designed based on the inverse of the developed physical model, thus reducing the computational effort in real-time calculation. The feedback controller was designed by using an H-infinity control theory by regarding the plant nonlinearities and the response delay of the actuators as uncertainties to the nominal model. The feedforward and feedback controllers were implemented as a two-degree-of-freedom control scheme. Further, an anti-windup scheme was introduced in the feedback controller to reduce the overshoot in the intake manifold pressure response. The effectiveness of the proposed method was evaluated by conducting not only simulations using the nonlinear physical model, but also experiments using a real Diesel engine.

14:40-15:00 FrA5.6

Real-Time MPC Design Based on Machine Learning for a Diesel Engine Air Path System (I), pp. 581-587

Moriyasu, Ryuta — Toyota Central R&D Labs., Inc
Ueda, Matsuei — Toyota Central R&D Labs., Inc
Ikeda, Taro — Toyota Central R&D Labs., Inc
Nagaoka, Makoto — Toyota Central R&D Labs., Inc
Jimbo, Tomohiko — Toyota Central R&D Labs., Inc
Matsunaga, Akio — Toyota Motor Corp
Nakamura, Toshihiro — Toyota Motor Corp

This study investigated a control design method based on machine learning to achieve non-linear model predictive control (MPC) at a low computational load. In addition, we describe examples of the application of this method to a diesel engine air path system. The solution to the optimal control problem determined at each point in time by MPC depends on several parameters at that time. Thus, if the relationship between the solution and the parameters could be approximated in advance using machine learning, solving this problem online would become unnecessary, and the control computation time could be reduced. We designed a controller that operates the valves of the air path system using this method and used a simulation to verify that this resulted in a favorable tracking performance of the target values. The computation time of the approximated MPC controller was 0.1 ms.

15:00-15:20 FrA5.7

Mega Knock Detection and Inhibition System for Turbo GDI Engine (I), pp. 588-591

Zhou, Xin — General R&D Inst. of China FAW Co., Ltd, Changchun, Jilin
Xin, Baiyu — General R&D Inst. of China FAW Co., Ltd
Li, JiaLing — General R&D Inst. of China FAW Co., Ltd
Sun, PengYuan — General R&D Inst. of China FAW Co., Ltd

Mega knock is an inevitable and destructive combustion phenomenon in gasoline engine, and the tendency of mega knock occurring in GDI turbocharged engine is more serious than other engine. So in order to protect the engine, a system which can detect mega knock and inhibit the occurrence of consecutive mega knock is proposed in this paper. Firstly, the knock sensor signal is translated to the integral value, and it is identified that whether a mega knock has happened based on the integral value. Finally, some methods such as fuel enrichment will be taken to inhibit mega knock in the next cycle. The experiment results of HIL verify that this system can detect mega knock occurrence accurately, and it is indicated by the thermodynamics theorem that the inhibit strategy is reasonable.

FrA6 The 3rd Meeting Room In South Zone

Vehicle Control (Regular session)

Chair: Liu, Zhiyuan — Harbin Inst. of Tech
Co-Chair: Guo, Hongyan — Jilin Univ

13:00-13:20 FrA6.1

Study on the Evaluation Model of Vehicle Comfort Based on the Neural Network, pp. 592-597

Huang, Fengnan — Beijing Inst. of Tech
Zhao, Changlu — Beijing Inst. of Tech
Huang, Ying — Beijing Inst. of Tech
Dai, Peilin — Beijing Inst. of Tech
Hao, Donghao — BEIJING Inst. of Tech
Yue, Yunpeng — Beijing Inst. of Tech

Due to the subjective perception of the driver, the comfort cannot be described by the objective indexes, meanwhile the normal subjective evaluation methods require plenty of human and material resources. Therefore, in this paper, in order to evaluate the comfort when the vehicle occurs low frequency longitudinal vibration during Tipin/out operations, a comfort evaluation method based on the neural network model is developed. First of all, through the mechanism analysis of the low frequency longitudinal vibration, three basic signals of the objective evaluation are determined. During different Tipin/out operations, the basic signals are collected by the experiment instruments and the subjective evaluation grades are determined by professionals. After that, the basic signals are weighted filtered and transformed into three objective evaluation indexes. Finally, the neural network model is trained by a large number of subjective evaluation grades and the objective evaluation indexes. The comfort performance of the vehicle during Tipin/out operations can be evaluated by the evaluation method.

13:20-13:40 FrA6.2

Using a 3-Dimensional Industrial Vehicle Model on Arbitrary Ground Geometries, pp. 598-604

Oei, Marius — Univ. of Stuttgart
Sawodny, Oliver — Univ. of Stuttgart

Dynamic driving assistance functions are beginning to enjoy popularity in the sector of industrial vehicles. Many such functions rely on a precise model of the vehicle dynamics.

In consideration of the usage scenarios (e.g. intralogistics) and specific properties of industrial vehicles, common simplified dynamics models for passenger cars and highway trucks are not suitable for an accurate description of the vehicle behavior.

In this work the relevant requirements are determined and a dynamic model for an industrial vehicle is presented. The model includes a kinematic description of the suspension, a flexible tire-ground interaction model for various ground surface profiles and supports trailer coupling forces with coupling backlash. Simulations of exemplary scenarios are used to verify the proposed vehicle model.

13:40-14:00 FrA6.3

Consistency Control of Multi - Agent System Based on Unknown Input Observer, pp. 605-610

Zhang, Niaona — Changchun Univ. of Tech
Niu, Wenjing — Changchun Univ. of Tech
Li, Taotao — Changchun Univ. Oftechnology

In this paper, a robust consistency control strategy for a class of nonlinear multi-agent systems with unknown input is designed. First of all, considering that the state of each agent is not measurable, and the time delay is inevitable in the signal transmission process, an unknown input observer with time-delay estimation is designed. Then the consistency control protocol of the multi-agent system is designed based on the estimator of the observer. Finally, the convergence of the system state synchronization error and the observer state error is verified by theoretical verification and simulation verification.

14:00-14:20 FrA6.4

Estimation Road Slope and Longitudinal Velocity for Four-Wheel Drive Vehicle, pp. 611-616

Yin, Zhenyu — Jilin Univ. Changchun Jilin China
Dai, Qikun — Jilin Univ. Changchun Jilin China
Guo, Hongyan — Jilin Univ
Chen, Hong — Jilin Univ. Campus NanLing
Li, Chao — China FAW Group Co., Ltd Res. Department

A method for estimating the velocity and road slope of a four-wheel drive vehicle based on full-order observer is proposed. First, we set up a simplified dynamic model of ramp driving which use the longitudinal acceleration as input. This paper use the longitudinal velocity and the longitudinal acceleration as the correction term respectively and design the nonlinear full-order observer of vehicle velocity; Secondly, design the estimation observer for road slope which used the estimation value of longitudinal velocity and longitudinal acceleration as inputs. Finally, we experimentally evaluate the recommended velocity and road slope estimation method on the high-precision vehicle dynamic software-veDYNA to verify the validity of the proposed observer. Then two ways of selecting correction terms are compared and analysed. The results show that the observer which uses the longitudinal velocity as the correction term has relatively higher accuracy.

14:20-14:40 FrA6.5

MPC-Based Slip Control System for In-Wheel-Motor Drive EV, pp. 617-621

Li, Shaosong — Changchun Univ. of Tech
Guo, Luping — Changchun Univ. of Tech
Zhang, Bangcheng — Changchun Univ. of Tech
Lu, Xiaohui — Changchun Univ. of Tech
Cui, Gaojian — Changchun Univ. of Tech
Dou, Jinglei — Changchun Univ. of Tech

A new slip control system for electric vehicles (EVs) equipped with four in-wheel motors is presented in this paper to solve the problem of the risk of locking up of EV wheels on brakes. This controller is designed on the basis of a model predictive control (MPC) scheme. Thus, the proposed MPC slip controller guarantees the optimal braking torque on each wheel by individually controlling the slip ratio of each tire within the stable zone over a considerably shortened response time. The wheel slip control performance is improved given the shortened response of the regenerative braking system. Theoretical analyses and simulation show that the proposed controller delivers an effective antilock performance.

14:40-15:00 FrA6.6

NMPC-Based Yaw Stability Control by Active Front Wheel Steering, pp. 622-627

Li, Shaosong — Changchun Univ. of Tech
Wang, Guodong — Changchun Univ. of Tech
Guo, Luping — Changchun Univ. of Tech
Li, Zheng — Changchun Univ. of Tech
Lu, Xiaohui — Changchun Univ. of Tech
Yu, Zhixin — Changchun Univ. of Tech
Cui, Gaojian — Changchun Univ. of Tech
Zhang, Jun — Changchun Univ. of Tech

This paper proposes a nonlinear model predictive control (NMPC) method for active front steering (AFS) system to improve vehicle

handling and stability performance at handling limits. Nonlinear vehicle and tire models are adopted in this proposed NMPC controller to describe the nonlinear dynamics of vehicle and tire. In addition, the nonlinear optimal problem is solved by nonlinear solver in MATLAB optimization toolbox. Finally, this study explores the effectiveness of the NMPC system through sine and double lane change maneuver. Results corroborate that the proposed NMPC system can enhance the yaw stability at the handling limits.

15:00-15:20 FrA6.7

A Piecewise Affine Robust Yaw Stability Control Method for In-Wheel Motor Electric Vehicle, pp. 628-633

Luo, Qian — Harbin Inst. of Tech
Liu, Zhiyuan — Harbin Inst. of Tech

Considering the nonlinear tire force and suspension K&C characteristic, this paper presents a piecewise affine robust yaw stability control method for the in-wheel motor electric vehicle. Using the piecewise linear to approximate front and rear tire force, and additional steering angle to describe the suspension K&C characteristic, a piecewise affine lateral dynamics model with uncertainty disturbance is firstly established. And then, by means of analysis of the dynamic behavior of front and rear tire force, the unreachable piecewise partition is neglected such that the lateral dynamics model is simplified. By using LMI technique, the yaw stability controller which can guarantee the closed-loop stability and Hinf disturbance rejection is obtained. Simulation results show that the yaw stability control method proposed in this paper is feasible and effective.

FrE2 Convention Room of Pines

HEV Energy Management (Regular session)

Chair: Liu, Teng — Univ. of Waterloo
Co-Chair: Zeng, Xiaohua — Jilin Univ

15:40-16:00 FrE2.1

Modeling and Analysis of Hybrid Compression Garbage Trucks, pp. 634-638

Sun, Qiang — Shandong Univ
Chengcheng, Ma — Jinan Vocational Coll
Fangke, Sun — Shandong Univ

As the main tool for collecting municipal solid waste, the fuel economy of compression garbage trucks (CGTs) has significant influence on the waste management budge. It is therefore crucial to decrease CGTs' fuel consumption. This paper proposes the use of oil-electric hybrid CGT for waste collection and transportation. In order to find out the factors that cause a high fuel consumption of CGTs, a CGT structure was analyzed and its working process was measured. The CGT's dynamic model was built in Cruise combined Matlab/Simulink and its validity was proved by measured data. According to the factors found above, a single-axle parallel hybrid system used in CGT was proposed and a dynamic model of it was established in Cruise combined with Matlab/Simulink. Based on the dynamic performance of traditional CGT, main components' parameters of hybrid system was matched. At last, the validity of the hybrid model is verified by comparison of the two models' simulation results.

16:00-16:20 FrE2.2

Fast Learning-Based Control for Energy Management of Hybrid Electric Vehicles, pp. 639-644

Liu, Teng — Univ. of Waterloo
Du, Guodong — Beijing Inst. of Tech
Zou, Yuan — Beijing Inst. of Tech
Cao, Dongpu — Cranfield Univ

In this paper, a fast learning-based control method is proposed for energy management of hybrid electric vehicles. First, the modeling of a parallel hybrid electric vehicle (HEV) is introduced. Ener-gy management of the parallel HEV is constructed as an optimization control problem. Then, the re-inforcement learning (RL) framework is depicted and a learning-based approach named Dyna-H al-gorithm is illustrated via incorporating a heuristic planning strategy into a Dyna agent. Finally, the proposed energy management strategy is compared with the benchmark methods to show its merits. Results indicate that the learning-based controls have better performance in fuel economy and cal-culation speed.

16:20-16:40 FrE2.3

LQR Based Battery Charge Sustaining Strategy for Hybrid Electric Vehicle, pp. 645-649

Song, Dafeng — Jilin Univ. State Key Lab. of Automotive Simulation
Sun, Chuqi — Jilin Univ. State Key Lab. of Automotive Simulation
Zeng, Xiaohua — Jilin Univ
Yang, Nannan — Jilin Univ. State Key Lab. of Automotive Simulation

Rule-based near-optimal control strategy derived from global optimization results has the best real-time performance among current online optimal control strategies of the hybrid electric vehicle. However, the battery charge sustainability based on the rule-based near-optimal control strategy is not theoretically studied in current researches, which is important for robust control in complex driving conditions. In this paper, a deviation correction strategy based on linear quadratic regulator (LQR) is proposed for a power-split hybrid electric bus in order to sustain the battery's state of charge (SOC). The LQR controller is designed according to an equivalent circuit model based on the state feedback control. Offline simulation is carried out to verify the proposed strategy under different driving cycles. Results show that, with the proposed strategy, the SOC can converge to a predefined value at the end of the optimization horizon.

16:40-17:00 FrE2.4

Energy Management of a Parallel Hybrid Electric Vehicle Equipped with a Voltage Booster, pp. 650-655

Hadj-Said, Souad — Univ. of Orléans
Colin, Guillaume — Univ. Orléans
Ketfi-Cherif, Ahmed — Renault
Chamaillard, Yann — Univ. of Orléans

In this paper, the optimization problem of energy management for a parallel hybrid electric vehicle equipped with a Step-Up converter is resolved analytically using Pontryagin'€s Maximum Principle (PMP). The analytical method is based on convex models, which are identified from the reference models. A numerical method based on the reference models is also used in order to validate the analytical method by comparing their results. In this work, two optimization variables are considered: the power split between the Internal Combustion Engine (ICE) and the Electric Machine (EM) and the output voltage of the booster. The simulation results show that the analytical approach reduces considerably the computing time and has an very low suboptimality comparing to the numerical method.

17:00-17:20 FrE2.5

Equivalent Consumption Minimization Strategy Based on Dynamic Programming for Plug-In Hybrid Electric Vehicle, pp. 656-661

Zheng, Qing — Jilin Univ
Yuan, Haorui — Jilin Univ
Wu, Jinzhu — Jilin Univ
Gao, Bingzhao — Jilin Univ

Equivalence factor plays a key role in equivalent consumption minimization strategy and due to its strong relevance with driving cycle, the change of driving cycle can be reflected by the equivalence factor and at the same time different driving cycle has different equivalence factor. In this paper, the optimal equivalence factor as one of the control variables is calculated by dynamic programming. The three initial maps of the optimal equivalence factor concerning state of charge and power demand are formulated over NEDC, UDDS, 10-15 mode cycle respectively. These maps are fused together to obtain the final one for simulation analysis. Compared with the rule-based control strategy, the proposed method has a better fuel economy over NEDC, UDDS, 10-15 mode cycle.

17:20-17:40 FrE2.6

Improved Energy Management Strategy of Hybrid Electric Vehicles with Varying Terrain, pp. 662-669

Biswas, Dhrupad — Indian Inst. of Tech. Kharagpur, India
Sengupta, Somnath — IIT Kharargpur
Mitra, Desham — Indian Inst. of Tech. Kharagpur, India
Mukhopadhyay, Siddhartha — Iit Kgp

Existing energy optimization strategies for HEVs generally do not consider mathematical justification for varying gradient within a drive cycle. It is demonstrated in this paper that variations in this factor can lead to significant inaccuracies in the prediction of energy and torque demands and consequently may not reliably follow the desired drive cycle completely. The proposed variants of these strategies for addressing this problem incorporate the factor of varying terrain in the cost function for generating optimal torque commands to ensure drivability and also manage battery charge so as to meet instantaneous torque demands imposed by the terrain within the drive cycle.

FrE3 — The 2nd Meeting Room In South Zone

Predictive Control of Powertrains (Regular session)

Chair: Egardt, Bo S. — Chalmers Univ. of Tech
Co-Chair: Li, Liang — Tsinghua Univ

15:40-16:00 FrE3.1

Stochastic MPC of Diesel Engines Using Traffic Information-Based Prediction of Driver's Torque Demand (I), pp. 670-675

Nishio, Yui — Sophia Univ
Shen, Tielong — Sophia Univ

This paper will discuss a real time optimal control of diesel engines. The driver demand torque is estimated as a probability density function by using the outside traffic information (i.e. traffic light and preceding vehicle and so on). The stochastic MPC using the probability of the future driver torque is introduced to determine the diesel engine control variables. Engine torque and pollutant emissions are constrained, and fuel consumption is minimized.

16:00-16:20 FrE3.2

Nonlinear Model Predictive Control for the Starting Process of a Free-Piston Linear Generator, pp. 676-683

Keller, Martin — RWTH Aachen Univ
Jochim, Bernhard — RWTH Aachen Univ
Abel, Dirk — RWTH-Aachen Univ
Beeckmann, Joachim — RWTH Aachen Univ
Pitsch, Heinz — RWTH Aachen Univ
Albin, Thivaharan — RWTH Aachen Univ

Free-piston linear generators (FPLG) attract a lot of attention and are under ongoing investigation due to their fuel effciency, low emissions and the compact design as generator unit. The main characteristic of FPLGs is the absence of a crankshaft, which poses a major challenge, because the piston moves freely. Hence, the locations of top dead center (TDC) and bottom dead center (BDC), have to be controlled precisely. In this contribution, an approach for modeling and control of a FPLG is presented. The combustion cylinder and the bouncing chamber on the opposite side are described with a physics-based, continuous-time thermodynamic model. For the starting process of the FPLG a nonlinear model predictive controller (NMPC) with multiple shooting discretization is designed for a safe and reliable starting process.

16:20-16:40 FrE3.3

Model Prediction Control of Fuel-Air Ratio for Lean-Burn Spark Ignition Gasoline Engine, pp. 684-689

Zhu, ChaoJie — Jilin Univ
Wang, Ping — Jilin Univ
Liu, ZiYang — Jilin Univ

Abstract: Higher fuel economy and lower exhaust emissions for lean-burn spark-ignition (SI) engines depend significantly on precise fuel-air ratio (FAR) control. In addition, in order to improve fuel economy and reduce emissions, it is crucial for lean-burn engine to change the FAR according to different operating conditions. However, the presence of large time-varying delay due to the engine combustion, exhaust emissions transmission and lean NOx trap (LNT) module in the engine is the primary limiting factor in the control of FAR. Hence, the FAR prediction control algorithm based on disturbance observer is proposed in this paper. First, a predictive model with time-delay characteristic is established. Second, state observer is designed to predict the future dynamic changes of the engine system, and disturbance observer is designed to estimate and predict disturbances. Finally, the physical constraints of the engine and the FAR control requirements are transformed into the optimization objective function, and the optimization problem is solved online to get the amount of fuel injection. The results of Matlab and GT-Power co-simulation show that FAR predictive control algorithm based on the disturbance observer not only can quickly track the desired FAR, but also can achieve a large range of precise control of FAR and reduce the delay and parameter uncertainty impact on system dynamics.

16:40-17:00 FrE3.4

Hierarchical MPC Control Scheme for Fuel Cell Hybrid Electric Vehicles, pp. 690-696

Liu, Shiqi — Beijing Univ. of Tech
Bin, Yang — Chongqing Univ. of Tech
Li, Yaoyu — Univ. of Texas at Dallas
Scheppat, Birgit — RheinMain Univ. of Applied Sciences

In this paper, we proposed a hierarchical model predictive control (H-MPC) strategy to optimize the efficiency of the polymer electrolyte membrane fuel cell (PEMFC) hybrid electric vehicles (HEV). A linearized control oriented FCHEV model is presented first. Then, we construct the H-MPC strategy control scheme, consisting of an upper and a lower-level MPC controller. The upper-level MPC controller is designed to optimize the power splitting ratio (PSR) between the PEMFC and battery pack, while the lower-level controller is used to realize the tracking of maximum PEMFC net output power, via optimizing the oxygen excessive ratio (OER). A convex polyhedral set is used as a constraint in the lower-level MPC controller to guaranty the safe operation of the compressor. The US06 driving cycle is adopted to evaluate the performance of the proposed method, and up to 7.79% equivalent fuel consumption is expected.

17:00-17:20 FrE3.5

Extended Model Predictive Control Based on Multi-Structure RBF Networks: Design and Application to Clutch Control, pp. 697-702

Huang, Chao — Tsinghua Univ
Li, Liang — Tsinghua Univ
Xiangyu, Wang — Tsinghua Univ

For many control systems in engineering practice, the nonlinear, slow time varying and multistage dynamics make it difficult to realize precise control. Therefore, the extended model predictive control (EMPC) based on multi-structure radial basis function neural networks (MSRBFNN) is proposed in this paper. To begin with, the standard model predictive model (MPC) is established from system analysis or identification to formulate the problem with known disturbances. Secondly, the original MPC is extended with radial basis function neural networks (RBFNN) to deal with the nonlinearity and slow time varying dynamics of the system. Further, considering that a single RBFNN is too complicated to cope with the multistage dynamics of the system for real time application, the MSRBFNN, composed of a series of simpler RBFNNs, is designed to replace the original RBFNN. The running system can then switch between different RBFNNs at different working conditions. Finally, a successive iteration method is introduced to derive the controller with nonlinear compensations and the stability issue is also discussed. Application to the dry clutch control system shows that the proposed method has a much better performance than the standard MPC. Moreover, it can also be extended to other similar nonlinear control systems.

17:20-17:40 FrE3.6

Decentralized Model Predictive Control for Polymer Electrolyte Membrane Fuel Cell System, pp. 703-708

Liu, Shiqi — Beijing Univ. of Tech
Bin, Yang — Chongqing Univ. of Tech
Li, Yaoyu — Univ. of Texas at Dallas
Scheppat, Birgit — RheinMain Univ. of Applied Sciences

In this paper, we applied a decentralized model predictive control (DMPC) scheme on the Polymer electrolyte membrane fuel cell (PEMFC) system. The DMPC controller is used to realize the tracking of the maximum PEMFC net output power. The scheme of DMPC is adapt from cite{alessio2011decentralized}. In the proposed DMPC control strategy, two DMPC controllers are designed to manipulate two key component of the PEMFC system, which are the compressor and the stack cathode. Each DMPC controller receives information from the local states, and calculate the optimal system input using an explicit feedback control law. The simulation results show the DMPC control scheme can successfully manipulate the PEMFC system to the optimal working condition, with acceptable performance loss compared to centralized model predictive control (CMPC) scheme.

FrE4 Meeting Room of Spring Dawn

Intelligent Management and Power Electronics Technology (Invited session)

Chair: Zhang, Chenghui — Shandong Univ
Co-Chair: Duan, Bin — Shandong Unieversity
Organizer: Zhang, Chenghui — Shandong Univ
Organizer: Duan, Bin — Shandong Unieversity
Organizer: Zhang, Qi — Shandong Univ
Organizer: Kang, Yongzhe — Shandong Univ

15:40-16:00 FrE4.1

An Improved Peukert Battery Model of Nonlinear Capacity Considering Temperature Effect (I), pp. 709-713

Zhang, Qi — Shandong Univ
Cui, Naxin — Shandong Univ
Shang, Yunlong — Shandong Univ
Duan, Bin — Shandong Unieversity
Zhang, Chenghui — Shandong Univ

The traditional Peukert's law is mainly used for lead-acid batteries at constant discharge, however, it ignores the temperature effect on battery nonlinear capacity. Thus, it is not accurate enough for the remaining capacity estimation of lithium batteries when temperature changes. As to this problem, an improved Peukert battery model (PeBaM) considering temperature effect is proposed to describe the nonlinear capacity characteristic of lithium-ion batteries. The experimental battery module has a capacity of about 30 Ah, which consists of 20 battery cells connected in parallel. The available capacity of battery module was analyzed at different discharge current and temperature in MKL battery test system. It was verified that the maximum error of available capacity of the tested battery module is only 2.02% in the proposed PeBaM.

16:00-16:20 FrE4.2

Study of YSC Used for All Electric Independent Driving and Braking Electric Vehicle Based on Fuzzy PI Control, pp. 714-719

Yang, Kun — Shandong Univ. of Tech
Wang, Jie — Shandong Univ. of Tech
Tan, Di — Shandong Univ. of Tech
Zhang, Xueyi — Shandong Univ. of Tech
Guo, Dong — Shandong Univ. of Tech
Liu, Ruijun — Shandong Univ. of Tech

Vehicle handling and stability performance is the premise of giving full play to the performance advantages of all electric independent driving and braking electric vehicle (abbr. AIDBEV). This paper presents the working principle of yaw stability control (abbr. YSC) used for AIDBEV. The YSC adopts fuzzy PI control algorithm. For verifying the control effect of YSC, a simulation platform based on fifteen degrees of freedom vehicle model is built. The sinusoidal steering with amplitude and period increasing is used for simulation. According to the simulation results, the yaw rate can be controlled near the target value when YSC works, but the vehicle is unstable when YSC does not work. Take front left wheel as an example, the maximum braking torque of EMB is reduced by 372.9Nm, accounting for 58% of the total braking torque, and the working time of EMB is reduced by 0.265s, accounting for 49.53% of total working time. This can provide potentiality to optimize EMB. By coupled brake, IWM can recover energy 18.77kJ. It has certain energy saving effect, too.

16:20-16:40 FrE4.3

Smart Vehicle Control Unit an Integrated BMS and VCU System (I), pp. 720-723

Zhu, Yunzheng — Hangzhou Gold Electronic Equipment Inc., Ltd
Qu, Shaofei — Shandong Univ

An effective electric vehicle control system is the key to ensure safe and efficient operation of electric vehicles. The traditional vehicle control system is usually divided into two parts: the vehicle control unit (VCU) and the battery management system (BMS). The reliability and real-time control of the vehicle control system have a large room for optimization. This paper presents a new type of electric vehicle intelligent vehicle control system (SVCU). The conventional vehicle control unit (VCU) and battery management system (BMS) is integrated into one system. The vehicle control of SVCU system is optimized. The battery information is directly obtained by CAN instead of passing through the BCU module, which greatly improves the real-time performance of the system and saves costs. In addition, the reliability of SVCU system has been verified through experiments such as electrical performance test, environmental test and EMC test.

16:40-17:00 FrE4.4

Hybrid Control Method for CLLLC Resonant Converter with Low Output Voltage Ripple (I), pp. 724-728

Song, Jinqiu — Shandong Univ
Yang, Dongjiang — Shandong Univ
Zhang, Chenghui — Shandong Univ
Duan, Bin — Shandong Unieversity

In this paper, a hybrid control method of pulse width modulation (PWM) and pulse frequency modulation (PFM) is proposed, which can greatly enhance the control performance of the CLLLC resonant converter to output voltage, reduce the ripple of the output voltage and improve the efficiency of the converter. This paper analyzes the theory of hybrid control and introduces the operating principle of the hybrid control method. In addition, the hybrid control method ensures that the power MOSFETs devices realize zero voltage switching (ZVS) and improve the efficiency of converter. Finally, the performance of the proposed hybrid control method is compared with the traditional PFM control and verified by simulation.

17:00-17:20 FrE4.5

A Bidirectional LLC-C Resonant DC-DC Converter Based on Normalized Symmetry Resonant Tank (I), pp. 729-733

Yang, Dongjiang — Shandong Univ
Duan, Bin — Shandong Unieversity
Ding, Wenlong — Shandong Univ
Song, Jinqiu — Shandong Univ
Zhang, Chenghui — Shandong Univ

A bidirectional LLC-C resonant converter with a normalized symmetry resonant tank is proposed for energy storage system. In the proposed LLC-C converter, two auxiliary switches are added to provide bypass path for each resonant capacitor. In either forward or backward operating mode, the converter can work as traditional LLC resonant converter, which has more methods to analysis and design. In addition, a design procedure is introduced to optimally design the LLC-C converters. An accurate algorithm based on enumeration of the ratio of two resonant inductors is introduced to find the required peak gain at the full load. Several design options can be evaluated and the optimal one can be selected for respective applications. At last, a simulation was performed with Simulink to verify the usability of the proposed topology and the effectiveness of the proposed design method.

17:20-17:40 FrE4.6

Design of High-Disturbance Driver System for SiC High-Power Module (I), pp. 734-737

Zhu, Liangtao — Qingdao MKL Tech. Corp
Wang, Tao — Shandong Univ
Song, Jinqiu — Shandong Univ
Li, Bin — Qingdao Meikai Lin Pol. Tech. Inc
Zhang, Jianguo — Qingdao MKL Tech. Corp

Compared to conventional Si power electronic device, the advantages of SiC power electronic device are high turn-off voltage, low on-resistance, high switching frequency and high efficiency. The high performance of the device is achieved by shortening the turn-on and turn-off times. However, the SiC power modules have higher dv/dt and di/dt, which leads to more CM (common mode) interference and DM (differential mode) interference certainly. In this paper, the operation principle of driver circuit is introduced firstly. Then, the high-disturbance driver system is verified by the SiC battery test and simulation equipment which is researched independently. In addition, an anti-interference driver circuit and driver line based on the actual engineering requirements are designed to decrease the CM interference and DM interference. Finally, the high anti-interference driver system for SiC power modules was verified by experiment.

FrE5 The 2nd Meeting Room In North Zone

Combustion Control (Regular session)

Chair: Dufour, Pascal — Univ. Lyon 1 - CNRS
Co-Chair: Hu, Yunfeng — Jilin Univ

15:40-16:00 FrE5.1

Partially Premixed Combustion (PPC) Stratification Control to Achieve High Engine Efficiency, pp. 738-743

Yin, Lianhao — Lund Univ
Turesson, Gabriel — Lund Univ
Yang, Tianhao — Dalian Univ. of Tech
Johansson, Rolf — Lund Univ
Tunestal, Per — Lund Univ. Faculty of Engineering

Partially premixed combustion (PPC) is a hybrid combustion of Homogeneous Charge Compression Ignition (HCCI) and Diesel Combustion (DC), which has a great potential in reducing the fuel consumption. PPC has a longer premixed time than DC but lesser than HCCI. Therefore it is more stratified than HCCI. This paper first presents results on how the stratification using multiple injections and different EGR influence the efficiency and proposes a control framework for PPC stratification control inspired from the experiments. The control framework is validated in transient operations. Results in both steady and transient operations demonstrated that the more stratified PPC with multiple injections has a lower fuel consumption.

16:00-16:20 FrE5.2

Recursive Engine In-Cylinder Pressure Estimation Using Kalman Filter and Structural Vibration Signal, pp. 744-749

Han, Runzhe — Clausthal Univ. of Tech
Bohn, Christian — Clausthal Univ. of Tech
Bauer, Georg — Clausthal Univ. of Tech

The cylinder pressure signal is a very useful indicator for modern high-performance internal-combustion (IC) engines. Unfortunately, direct measurements of the cylinder pressure are impractical because installing cylinder transducers is difficult and the conditions in IC engine cylinders are adverse. Therefore, different methods have been investigated to reconstruct the cylinder pressure from externally measured signals, such as the engine structure vibration and the crank angular speed. In this paper, some of existing methods are reviewed firstly. Then a novel recursive cylinder pressure estimation method based on using the Kalman filter with the engine structure vibration signal as input is proposed. Two combustion metrics, pressure peak (Pmax) and peak location (Ploc), were used for evaluating the proposed method. The estimation results were compared with the experimental data collected from a four-cylinder diesel engine and showed the effectiveness of the proposed method.

16:20-16:40 FrE5.3

Predictive Pressure Control with Multiple Injections, pp. 750-757

Turesson, Gabriel — Lund Univ
Yin, Lianhao — Lund Univ
Johansson, Rolf — Lund Univ
Tunestal, Per — Lund Univ. Faculty of Engineering

This paper introduces a predictive combustion-engine controller for efficient fulfillment of constraints on peak pressure, pressure-rise rate, exhaust temperature and NO emissions. The controller utilizes

a in-cylinder pressure sensor, actuation of multiple fuel injections and numerical optimization. A physical model is used to predict pressure changes due to fuel-injection variation. The predicted pressure is used to compute changes in fuel-injection timings and durations by solving a model-predictive control problem every engine cycle. A method for separating the heat-release among different injections is presented along with a method for varying the number of injections, since the optimal number of injections varies with operating conditions. Experimental results are presented showing controller performance in the mid-load region of a Scania D13 heavy-duty engine, running on a gasoline fuel.

16:40-17:00 FrE5.4

Nonlinear Model Predictive Controller Design for Air System Control of Variable Geometry Turbocharged Diesel Engine, pp. 758-763

Li, Na — Jilin Univ
Gao, Wei — Jilin Univ
Hu, Yunfeng — Jilin Univ

Abstract: Variable geometry turbocharger (VGT) is a key technology and has become a development trend in the diesel engine industry because it can reduce turbo lag and improve fuel economy. In this paper, nonlinear model predictive control (NMPC) method for VGT is developed to solve the air system control problem of turbocharged diesel engine. Firstly, a model of the turbocharged diesel engine was built in AMESim. Secondly, the desired torque is converted into the desired exhaust manifold pressure through the look-up table. Thirdly, The VGT controller based on NMPC is designed to achieve the desired exhaust manifold pressure tracking while considering constraints on the system input and output. Finally, the effectiveness of the VGT controller is verified.

17:00-17:20 FrE5.5

Dynamic Indicated Torque Estimation for Turbocharged Diesel Engines Based on Back Propagation Neural Network, pp. 764-769

Hao, Donghao — BEIJING Inst. of Tech
Zhao, Changlu — Beijing Inst. of Tech
Huang, Ying — Beijing Inst. of Tech
Li, Gang — Beijing Inst. of Tech
Zeng, Wenwen — Beijing Inst. of Tech
Li, Hong — Beijing Inst. of Tech

An indicated torque estimation model is presented for turbocharged diesel engines considering both steady-state and transient operating conditions. The proposed model consists of two submodels: a steady-state indicated torque model and a transient torque coefficient model. By combining the steady-state torque with the transient torque coefficient from the two proposed submodels, dynamic indicated torque is obtained. The transient torque coefficient is calculated by training a designed back-propagation neural network (BPNN) using transient test data obtained from the designed experiments based on a DEUTZ BF6M1015 turbocharged diesel engine bench. Only the engine speed, the cycle fuel quantity and the intake air pressure are needed for dynamic torque estimation. The generalization capacity and dynamic torque estimation accuracy of the torque estimation model are validated. The maximum error of the estimated torque is within 8% while the average error is within 2% in both fuel step change and slow change conditions.

17:20-17:40 FrE5.6

Experiments Design for Waste Heat Recovery Modeling in Heavy Duty Trucks, pp. 770-775

Galuppo, Francesco — Volvo Trucks, Univ. Lyon, Univ. Claude Bernard Lyon 1, CNRS,
Dufour, Pascal — Univ. Lyon 1 - CNRS - EZUS
Nadri, Madiha — Univ. Claude Bernard Lyon 1
Reiche, Thomas — Volvo Trucks
Lemort, Vincent — Thermodynamics Lab. Univ. of Liège

Transient working conditions of a waste heat recovery (WHR) system in a heavy-duty (HD) truck application require the control of internal variables of the thermodynamic Rankine cycle for the final large scale commercial integration of this technology. The intensive test demand and the large number of possible operating points of the HD truck engine suggest paying particular attention to the choice of the engine working points to use for model identification needed in further control design. This paper presents a methodology for the design of the engine working points to test in experiments in order to proceed to an open loop multi-linear and multi- structure model identification task from experimental data.

FrE6 The 3rd Meeting Room In South Zone

Advanced Design and Control for Energy Efficient Powertrain (Invited session)

Chair: Zhang, Hui — The Ohio State Univ
Co-Chair: Yang, Fuyuan — Tsinghua Univ
Organizer: Zhang, Hui — The Ohio State Univ
Organizer: Ni, Jun — Beijing Inst. of Tech
Organizer: Meng, Fei — Shanghai Maritime Univ

15:40-16:00 FrE6.1

Application of Multi-Agent Consistency Analysis Based on Finite State Machine in Driverless Vehicles Formation Control, pp. 776-781

Zhang, Niaona — Changchun Univ. of Tech
Zhang, Xiaofang — Changchun Univ. of Tech

The consensus problem in directed networks of multi-agents under fixed topology is studied. A second-order sliding mode control algorithm based on finite state machine is applied to mult-iagent system. Under the condition that the first derivative of sliding mode is unknown, the control output is generated by switching between multiple state machines according to the measured value of sliding mode, so that the sliding mode and its first derivative converge to zero in a finite time, and to achieve the goal that the multi-agent system can be consistent for a limited period of time.Finally, the multi-agent control idea based on finite state machine is applied to driverless vehicles formation control. The results show that this method can be successfully applied to driverless vehicles formation control.

16:00-16:20 FrE6.2

The Design of Driverless Vehicle Trajectory Tracking Control Strategy (I), pp. 782-789

Li, Yunxiao — Beijing Inst. of Tech
Ni, Jun — Beijing Inst. of Tech
Hu, JiBin — Beijing Inst. of Tech
Pan, Bo — Beijing Inst. of Tech

At present, driverless vehicles have become another important development direction for emancipating mankind. As far as the development stage of driverless vehicles is concerned, trajectory tracking capability is a very important part, and its control effect has a greater impact on driverless vehicles. Nowadays, the research on trajectory tracking control strategy has limited application to vehicle dynamics. This paper will design a trajectory tracking strategy for driverless vehicles based on vehicle dynamics. Firstly, we establish a 7-DOF dynamic model of vehicle. And the Magic Formula tire model is built based on the experimental data. Then we design trajectory tracking control strategy. Through the vertical and horizontal control of the driverless vehicle, the stability limit can be achieved and the accuracy of trajectory tracking can be guaranteed.

In view of the designed trajectory tracking control strategy, the principle prototype vehicle is used to verify. The experimental results show that the proposed trajectory tracking control strategy works well and achieves the goal of achieving the stability limit and ensuring the accuracy of trajectory tracking.

16:20-16:40 FrE6.3

A Comparative Study of Different Hybrid Electric Powertrain Architectures for Heavy-Duty Truck, pp. 790-797

Xu, Chao Tsinghua Univ
Guo, Kun Fang Tsinghua Univ
Yang, Fuyuan Tsinghua Univ

In this paper, three different hybrid electric powertrain architectures are compared based on a heavy-duty truck running the Chinese-World Transient Vehicle Cycle (C-WTVC). The fuel consumption and battery costs of the different architectures are optimized by using the dynamic programming (DP) approach, based on a dynamic degradation model of the LiFePO4 battery. Based on the DP results, near-optimal rule-based control strategies of different powertrains for on-line uses are proposed. Finally, the three architectures are comprehensively compared from different aspects, including fuel economy, initial cost, and payback period in the total cost of ownership. Simulation results show that all architectures have their merits and drawbacks, and can be used in different applications with different requirements. In addition, more than 18% fuel economy improvement is achieved when compared to the traditional heavy-duty truck. Under economic scenarios assumptions made, the payback period for hybrid electric heavy-duty trucks are less than six years for the Chinese-World Transient Vehicle Cycle. When economic scenarios assumptions are beneficial toward electrification of vehicles, the shortest payback period will be only three years.

16:40-17:00 FrE6.4

Accurate Trajectory Tracking with Disturbance-Resistant and Heading Estimation Method for Self-Driving Vibratory Roller (I), pp. 798-802

Xie, Hui Tianjin Univ
Yao, Dongchun Tianjin Univ
Qiang, Wei Tianjin Univ
Liu, Yuguang Tianjin Univ
Xiong, Shuo Tianjin Univ

Applying self-driving technology in engineering machinery is highly expected to decrease driver's fatigue and speed up construction schedule. Single drum vibratory roller is widely used in road and dam construction. This paper discusses the steering kinematics of a center-articulated roller and analysis the relationship between articulation angle and turning radius. Extended state observer is proposed to observe disturbance during vibration compaction on rough road. Based on the road curvature information in the preview distance, the feedforward steering angle is calculated with a pure-pursuit navigational algorithm. Feedback control combines current heading collected from inertial navigation system and estimated heading calculated by a heading prediction algorithm, which aimed to compensate the heading response lag. Simulation results show that an articulated drum roller can converge to the desired straight-line and circular arc trajectory with the proposed method.

17:00-17:20 FrE6.5

Active Disturbance Rejection Control for Selecting and Shifting Motor of Automated Mechanical Transmission (I), pp. 803-808

Zhang, Guohui Tianjin Univ
Xie, Hui Tianjin Univ
Chen, Tao Tianjin Univ
Ruan, Diwang Tianjin Univ
Zhang, Ruichang Tianjin Univ
Tong, Qiang Tianjin Univ

The control strategy of shifting actuators is the most crucial part in the development of automated mechanical transmission (AMT) system. To solve problems such as large workload of parameters tuning and worse disturbance-rejecting ability under traditional PID for selecting and shifting gear in present industry, a new strategy based on active disturbance rejection control (ADRC) was proposed. The extended state observer (ESO) was used to observe and compensate total disturbances in real time to achieve precise closed-loop control for shifting motor position. The Hardware-In-the-Loop (HIL) experiments show that the speed of selecting actuator moving to target position under ADRC is 14.3% faster than that of PID, and the position deviation of selecting actuator is 0.9mm under ADRC with an external disturbance of 1N·m added, which is 59.1% less than that under PID. And the target gear tracking test indicates that the total shifting time under ADRC can be reduced by 2.37% to 5.08% compared with PID. This strategy has better control accuracy and robustness under load mutation condition compared to traditional PID.

17:20-17:40 FrE6.6

Robust Detection Using Sparse Laser Scanner with Autonomous Race Car (I), pp. 809-814

Pan, Bo Beijing Inst. of Tech
Ni, Jun Beijing Inst. of Tech
Hu, JiBin Beijing Inst. of Tech

In this paper, a novel laser detection approach with lower objects is proposed. The detection method is based on RANSAC and another filter. For RANSAC, it detects ground surface and delete it in different driving condition. After that using Cluster, it can divide points into different groups which represents objects. Finally, there is a modified Formula SAE race car designed by author to finish experiment to test approach. We apply cones to combine track and do experiment in a random track to analysis the accuracy of detection.

Technical Program for Saturday September 22, 2018

SaM1	Conference Room of Pine Billows
New Energy and Intelligent Vehicle Technology (Invited session)	
Chair: Xiong, Lu	Tongji Univ
Co-Chair: Wang, Yafei	Shanghai Jiao Tong Univ
Organizer: Xiong, Lu	Tongji Univ

09:45-10:05 SaM1.1

Design of an Active Collision Avoidance System for a 4WIS-4WID Electric Vehicle (I), pp. 815-821

Hang, Peng — Tongji Univ
Han, Yanqun — Tongji Univ
Chen, Xinbo — Tongji Univ
Zhang, Bang — Tongji Univ

A novel four-wheel independent steering and four-wheel independent drive (4WIS-4WID) electric vehicle (EV) is proposed in this paper, which is regarded as an autonomous ground vehicle (AGV). Then, the active collision avoidance system of the 4WIS-4WID EV is designed, which mainly consists of the path planner design and the path-tracking controller design. Clothoid is used to planning the collision avoidance path and robust H∞ controller is applied to path tracking. To evaluate the performance of the active collision avoidance system for the 4WIS-4WID EV, two simulation conditions are carried out. The simulation results indicate that the active collision avoidance system has good collision avoidance performance and robust performance, and the 4WIS-4WID EV has better path-tracking performance and handling stability than active front-wheel steering (AFS) vehicles.

10:05-10:25 SaM1.2

A 3D Estimation of Structural Road Surface Based on Lane-Line Information (I), pp. 822-827

Xiong, Lu — Tongji Univ
Deng, Zhenwen — Tongji Univ
Zhang, Peizhi — Tongji Univ
Fu, Zhiqiang — Tongji Univ

Another kind of 3D estimation method for structural road surface based on traffic lane line information is proposed. Firstly, B-spline which is a semi-parametric model is selected to describe the lane line on the road. In the process of B-spline fitting, Image District Extraction is utilized to divide road pixels into small part Region of Interest (ROI), and Hough Transform and Least Squares Method are applied to fit short line in each ROI. The center point of the short line is taken as control point to generate B-spline curve. Finally, with the help of Similarity Transformation principle, point cloud is generated by comparing the road width between in image and on road. Experiments show that structural road can be described as 3D point cloud according to the information of lane line, and the height change of the frontal road surface can be detected from the 3D point cloud.

10:25-10:45 SaM1.3

Research on Drowsy-Driving Monitoring System Based on Multi-Feature Comprehensive Evaluation (I), pp. 828-833

Ma, Zhipeng — Jilin Univ
Shuwan, Yao — Jilin Univ
Zhao, Jian — Jilin Univ
Qian, Jingjiu — Jilin Univ
Su, Jun — Jilin Univ
Dai, Jingshuang — Jilin Univ

Drowsy driving is a major cause of traffic accidents. Based on the theory of comprehensive evaluation, a driving fatigue evaluation program, that combines the four indicators of eye movement, Electromyogram (EMG), Electrocardiograph (ECG), and grip force, is proposed in this paper. First, the fatigue evaluation models of each indicator are studied. The eyeballs are located using the segmentation method and the eye movement is judged by the PERCLOS eigenvalues. The median frequency is used to evaluate EMG, the standardized high-frequency power is used to evaluate ECG and the mean change rate is used to evaluate grip strength. Then, the principal component analysis (PCA) method is applied to determine the weight coefficient, and the comprehensive evaluation method is constructed with the maximum criterion of the decision theory. Based on this, a comprehensive evaluation algorithm is designed and the normalized comprehensive evaluation eigenvalue can be obtained. Finally, the fatigue alarm algorithm and corresponding system are designed, and its performance is verified by tests.

10:45-11:05 SaM1.4

Longitudinal Velocity Tracking Control of a 4WID Electric Vehicle (I), pp. 834-839

Hang, Peng — Tongji Univ
Chen, Xinbo — Tongji Univ
Zhang, Bang — Tongji Univ
Tang, Tingju — Tongji Univ

A novel four-wheel independent drive (4WID) electric vehicle (EV) is proposed as an autonomous ground vehicle (AGV) in this paper. Since longitudinal motion control is the fundamental problem of autonomous vehicle control, a traditional sliding mode control (SMC) algorithm and an improved adaptive sliding mode control (ASMC) algorithm using Radial Basis Function (RBF) neural network are applied to longitudinal velocity tracking controller design. To evaluate the performance of the designed controllers for the 4WID EV, two simulation maneuvers are carried out including straight line condition and single lane-change condition. The simulation results indicate that the longitudinal velocity tracking controller using ASMC has smaller tracking error and better disturbance rejection performance than SMC.

11:05-11:25 SaM1.5

Steering Angle Control of Autonomous Vehicles Based on Active Disturbance Rejection Control (I), pp. 840-844

Xiong, Lu — Tongji Univ
Jiang, Yehan — TongJi Univ
Fu, Zhiqiang — Tongji Univ

The tracking control to achieve desired steering angle is significant for autonomous vehicles. This paper deals with the steering angle control using the steering actuator in autonomous vehicles with electric power steering (EPS) system or steer-by-wire (SbW) system. Mathematical model of the steering system is presented. Based on the analysis of the nominal model, active disturbance rejection control (ADRC) is applied to estimate the tire self-aligning moment and calculate the steering torque. In the end, the numerical simulations are conducted to verify the proposed steering angle controller.

11:25-11:45 SaM1.6

Consensus-Based Platoon Forming for Connected Autonomous Vehicles (I), pp. 845-850

Wu, Jingkai — Shanghai Jiao Tong Univ
Wang, Yafei — Shanghai Jiao Tong Univ
Wang, Lin — Shanghai Jiao Tong Univ
Shen, Zhaokun — Shanghai Jiao Tong Univ
Yin, Chengliang — Shanghai Jiao Tong Univ

Connected Autonomous Vehicles(CAV) utilizing the shared information like vehicle positions, headings and velocities facilitate the possibility of coordinated driving. Platoon is one of the most promising application where a line of vehicles join in the same lane

with close and steady spacing in the longitudinal direction. This paper applies a consensus control scheme to platoon formulation task carried out by vehicles from separate lanes, along with a vehicle dynamics model incorporating kinematics states with vehicle control parameters. Collisions among the vehicles are avoided through designed repulsive forces and final states are reachable through stability analysis. Simulation is carried out on a constructed 3-vehicle straight roadway scenario with different desired velocities, proving the effectiveness of the proposed method.

SaM2 Convention Room of Pines

Transient Control and Optimization for Engines (Invited session)

Chair: Song, Kang — Tianjin Univ
Co-Chair: Wang, Yang — Shandong Univ
Organizer: Xie, Hui — Tianjin Univ
Organizer: Song, Kang — Tianjin Univ

09:45-10:05 SaM2.1

Modelling and Composite Control of Fuel Quantity Actuator System for Diesel Engines, pp. 851-856

Sun, Hao — Southeast Univ
Dai, Chen — Southeast Univ
Li, Shihua — Southeast Univ

Fuel quantity actuator is a core component in electronically controlled distributor pump which is used to control the fuel injection quantity for diesel engines. In the fuel quantity actuator system, there exist nonlinearities, disturbances and only the position angle can be measured directly. Previous researches usually neglect the nonlinearities of the system and obtain the angular speed by taking the derivative of the position angle. However, it is difficult for linear output feedback controllers to achieve high performance in the nonlinear system. Thus, it is essential to compensate the influence of system nonlinearities and disturbances. This paper establishes the mathematical model of the fuel quantity actuator system and presents an extended-state-observer(ESO)-based backstepping control (BSC) approach. And the stability analysis is provided to show that the closed-loop system is asymptotically stable in the presence of the lumped disturbance. While providing a superior property of transient performance, the proposed control strategy reveals a promising disturbance rejection performance as well. Both feasibility and efficiency have been validated by experiments based on the dSPACE real-time control test setup.

10:05-10:25 SaM2.2

Fuel-Optimal Periodic Control of Passenger Cars in Cruise Based on Pontryagin's Minimum Principle, pp. 857-864

Shen, Daliang — Argonne National Lab
Karbowski, Dominik — Argonne National Lab
Rousseau, Aymeric — Argonne National Lab

This paper aims to exploit the fuel saving potential of a passenger car in cruising scenarios by deriving an optimal periodic control strategy based on Pontyagin's Minimum Principle. Gear shifting and coupling between the engine and the driveline are explicitly included in the optimal control problem, and this leads to a hybrid system. By investigating the analytically derived optimal trajectory in the state space, we confirm the optimal periodic control. Considerable advantages in fuel economy up to 4.8% compared to conventional steady control are demonstrated.

10:25-10:45 SaM2.3

Vibration Measurement for Combustion Phase Evaluation in a CI Engine (I), pp. 865-870

Wang, Yang — Shandong Univ
Cheng, Yong — Shandong Univ

Combustion phase parameters of internal combustion engines are important for closed-loop control of combustion process. As an indirect method for combustion diagnosis, engine surface vibration can be used to extract combustion related information. In this paper, a vibration velocity sensor mounted on the cylinder head was used to detect engine vibration signals. The high components of measured vibration signals are highly related to combustion and distribute in the crank angle area -30~90°. Ensemble Empirical Mode Decomposition (EEMD) method was used to extract combustion induced vibration signals and the feature points on the sixth Intrinsic Mode Function (IMF) can be used to evaluate start of combustion (SOC) and location of 50% mass fraction burn (CA50). The maximum errors of identified SOC and CA50 are 1.1° and 1.4°, respectively.

10:45-11:05 SaM2.4

Indicated Torque Estimation of Gasoline Direct Injection Engine Via Optimized Model-Based Observer (I), pp. 871-876

Tong, Qiang — Tianjin Univ
Xie, Hui — Tianjin Univ
Zou, Dong — Tianjin Univ
Ruan, Diwang — Tianjin Univ

The indicated torque (TQin) is regarded as a key variable for both control and diagnostics of the combustion of gasoline engines. Due to the limitation in available sensors, the TQin, however, cannot be measured directly. In this paper, a real-time TQin estimation approach is presented, based on the instantaneous crankshaft rotational speed (ω) signal. A physics-based control-oriented model ω is developed for a four-cylinder gasoline direct engine, which takes account the load torque, friction torque and the indicated torque. The proposed observer are validated both in simulation and experiments at steady-state operating and during transients. Results show that deviation between the observed value and the actual value is within 4%. The optimized model based observer shows greater potential in engine combustion feedback control.

11:05-11:25 SaM2.5

MAP Learning and Disturbance Observation Based Engine Torque Control for Dynamometer Test Bench (I), pp. 877-883

Ruan, Diwang — Tianjin Univ
Xie, Hui — Tianjin Univ
Song, Kang — Tianjin Univ
Zhang, Guohui — Tianjin Univ
Qiang, Tong — Tianjin Univ

For the engine-dynamometer test bench, the engine torque output is controlled by the test bench controller through the manipulation of the engine acceleration pedal position. Due to the nonlinearities and uncertainties between engine torque and acceleration pedal position, the time-consuming control parameters scheduling is usually necessary using conventional controllers. In this paper, a composite disturbance observation based torque controller is proposed. The nonlinearity, from acceleration pedal position to the torque demand in the engine control unit (ECU), is compensated by an adaptive feed forward controller, based on the inverse of a self-learning MAP by stochastic gradient decent (SGD). All other nonlinearities and uncertainties are lumped as total disturbance. By estimating the total disturbance using the extended state observer (ESO) in real-time, the plant is enforced as a first-order system to be easily controlled by a simple proportional controller. The proposed controller is validated in a high-fidelity GT-SUITE simulation model. Results show that average absolute torque tracking error is 1.62N•m over the suburban part in European Transient Cycle (ETC) without the need of control parameters scheduling.

11:25-11:45 SaM2.6

Introducing Compressed Mixture Models for Predicting Long-Lasting Brake Events, pp. 884-889

Staf, Emil — Volvo Cars
McKelvey, Tomas — Chalmers Univ. of Tech

With tougher restrictions on emissions the automotive industry is in dire need of additional functionality to reduce emissions. We conduct a case study trying to predict long-lasting brake events, to support the decision-making process when the engine can beneficially be put to idle or shut down to achieve emission reduction. We introduce Compressed Mixture Models, a mixed variate kernel density model featuring online complexity reduction and training, and use it for prediction purposes. The results show that the proposed method produces comparable prediction results as a Random Forest Classifier and outperform a Support Vector Classifier. On a rural road a prediction accuracy of 87.4 % is obtained, while a prediction accuracy of 76.4 % on a highway segment using the proposed method. Furthermore, it is possible to use a trained Compressed Mixture Model as a tool for statistical inference to study the properties of the observed realization of the underlying random variables.

SaM3 — The 2nd Meeting Room In South Zone

Cruise, Driving, and Control (Regular session)

Chair: Eriksson, Lars — Linköping Univ
Co-Chair: He, Lin — Tsinghua Univ

09:45-10:05 — SaM3.1

Energy-Optimal Adaptive Cruise Control in Time Domain Based on Model Predictive Control, pp. 890-897

Jia, Yanzhao — DENSO AUTOMOTIVE Deutschland GmbH
Saito, Tomohiro — DENSO AUTOMOTIVE Deutschland GmbH
Itoh, Yutaro — DENSO Corp
Nukezhanov, Yernar — Univ. of Kaiserslautern
Görges, Daniel — Univ. of Kaiserslautern

This paper presents a novel energy-optimal adaptive cruise control (EACC) strategy based on model predictive control (MPC). The EACC has three main objectives: a) reduce the real driving fuel consumption of the controlled car; b) the controlled car has good ability of tracking its preceding car; c) the controlled car strictly keeps the minimum safety distance to its preceding car. For this multi-objective optimal control, it is important to build up a suitable problem formulation to describe various control targets properly. In this paper, three different methods of problem formulation for MPC-based EACC in time domain are proposed, deeply analysed and compared in real driving situations. In addition to the importance of the problem formulation, the prediction information such as the future speed of the preceding car also has a considerable influence on MPC-based control. Therefore, how the prediction information affects the performance of EACC in different driving situations is investigated. Furthermore, the impact of the prediction horizon's length on MPC is analysed in this work.

10:05-10:25 — SaM3.2

A Study on the Construction of Hefei Urban Driving Cycle for Passenger Vehicle, pp. 898-902

Liu, Bingjiao — Hefei Univ. of Tech
Shi, Qin — Hefei Univ. of Tech
He, Lin — HeFei Univ. of Tech
Qiu, Duoyang — Hefei Univ. of Tech

NEDC is widely used in China, however, it is not really appropriate for the current Chinese road conditions. This paper take the typical urban roads in Hefei City as the research object. Collected data ,including type of road, traffic density and time factors, were divided into kinematic segments. In order to reduce the dimensionality of the kinematic parameters and classify kinematics segments, Principal component analysis and k-means clustering method were applied. According to the length of time and the correlation of each class, some kinematic segments were selected,forming the representative driving cycle. Through the error analysis, it can be seen that the synthetic driving cycle can reflect the traffic condition of the actual condition in Hefei urban road accurately.

10:25-10:45 — SaM3.3

Car-Following Model-Based Stochastic Distance Regulation between Vehicles, pp. 903-906

Li, Jingwei — Shandong Jiaotong Univ
Zhao, Changli — Shandong Jiaotong Univ
Yue, Hongwei — Shandong Jiaotong Univ
Fu, Wenjun — Shandong Jiaotong Univ

The problem of car-following model-based stochastic distance regulation between vehicles with consideration of the disturbance caused by the sensitivity of the driver is researched in this paper. An stochastic distance regulator is designed based on the car-following dynamic model, for the purpose of distance regulation between vehicles. The validation of the proposed stochastic regulator is given by the numerical simulation. The simulation results show that the distance between vehicles can be regulated to a neighbourhood of its desired value under various working conditions.

10:45-11:05 — SaM3.4

An Improved Artificial Potential Field Model Considering Vehicle Velocity for Autonomous Driving, pp. 907-911

Hu, Hongyu — Jilin Univ
Zhang, Chi — State Key Lab. of Automotive Simulation and Control, Jilin
Sheng, Yuhuan — State Key Lab. of Automotive Simulation and Control, Jilin
Zhou, Bin — State Key Lab. of Automotive Simulation and Control, Jilin
Gao, Fei — State Key Lab. of Automotive Simulation and Control, Jilin

Path planning is one of the most crucial technologies for autonomous driving. An improved artificial potential field method considering vehicle velocity for path planning is presented in this paper. At first, a combined artificial potential field model is proposed, which includes five components, target potential, road potential, lane potential, vehicle potential and velocity potential. Road potential and lane potential considers the road structure and traffic rules in highway driving. In addition, for vehicle potential, a potential field model is constructed with the absolute velocity and relative velocity which influences the safe distance between the host vehicle and the obstacle vehicle. The design of velocity potential is to prevent unnecessary lane changing behavior. Finally, the collision avoidance path for autonomous driving is calculated with gradient method from the superposition of disparate potential function. According to the simulation experimental validation, the results show the proposed method can achieve good performance for autonomous driving in highway.

11:05-11:25 — SaM3.5

Time Optimal Turbocharger Testing in Gas Stands with a Known Map, pp. 912-919

Johansson, Max — Linköpings Univ
Ekberg, Kristoffer — Linköping Univ
Eriksson, Lars — Linköping Univ

Turbocharger maps are used in design, evaluation and optimization of engine system operation to represent the turbo operation in different scenarios. To construct such a map, the turbo is tested in a

gas flow test bench, called gas stand. Turbo testing is a time and resource consuming experimental process. The turbo is tested in a selected number of test points for different turbo rotational speeds, where the temperatures in the turbo have to be stationary when the measurements that constitute the map are acquired. In this paper, optimal control is used to find the most time efficient pattern of test conditions, and the optimal control strategy to traverse between them. A heat transfer model, describing the heat transfer between the compressor, bearing house, and turbine, is presented and validated against measured data. A direct collocation method is used to find time optimal control trajectories between the specified test points in the map. The method objective is to find the least time consuming control strategy which brings the turbo from one test point to the next, while ensuring thermal equilibrium at the final time. The results suggest that this method reduces turbocharger testing time with a factor higher than 60. The improvements can be further increased, with over 70 times, if a traveling salesman problem is solved to find the optimal route through the turbo map. The described method would be able to map a 43 points turbo map in 22 minutes, including a 5 minute warm-up phase.

11:25-11:45 SaM3.6

An Economic Model Predictive Cruise Controller for Electric Vehicles Using Gaussian Process Prediction, pp. 920-925

Morlock, Florian — Univ. of Stuttgart
Sawodny, Oliver — Univ. of Stuttgart

Recent political decisions in most developed countries urge car manufacturers to reduce vehicle emissions and fuel consumptions, essentially through development of hybrid and battery electric vehicles. Alongside with transfer to electro mobility, many OEMs promote research in car2x communication and cloud services as such connectivity features offer new opportunities to vehicular technology.

This work presents a framework for an economic cruise controller for electric vehicles (EVs) utilizing traffic speed data obtained from a cloud server and aiming for real time applicability. Within the scope of this research, an economic model predictive cruise controller based on leading vehicle speed prediction is designed. Novelty of this approach is to utilize real time traffic speed data which significantly improves leading vehicle speed prediction. Error in speed prediction is compared to existing approaches and computed energy consumption using model predictive control is analyzed and discussed for different approaches of leading vehicle speed prediction.

SaM4 Meeting Room of Spring Dawn

Driveline Control Technologies (Regular session)

Chair: Mrochen, Michael A. — Univ. of Stuttgart, Germany
Co-Chair: Liu, Qifang — Jilin Univ

09:45-10:05 SaM4.1

Positon Control of an Electric Clutch Actuator for 2-Speed I-AMT, pp. 926-929

Zhang, Zhenwei — Jilin Boatran Transmission System Tech. Co., Ltd
Zhang, Jie — Jilin Univ
Yin, Ni — Jilin Univ
Yue, Hanqi — Jilin Boatran Transmission System Tech. Co., Ltd

A novel kind of I-AMTs is adopted for pure electric vehicle, which uses overrunning clutch to replace the sleeve to realize smooth shift without power interruption. A nonlinear-feedward-feedback controller is designed for its electric clutch actuator that includes a dc motor, a set of worm gear, worm and linkage mechanism to implement the motion control. However, the nonlinear load force and the nonlinear characteristics of linkage mechanism increase the difficulty. The designed controller includes two parts: the feedforward controller was designed to settle system nonlinearities and the feedback controller was designed to guarantee the reliability of the controller. Experiments result show that, compared with PID controller, the designed controller can provide better performance and keep the system stable at the same time.

10:05-10:25 SaM4.2

Modeling and Simulation of a Hybrid Dual-Clutch Transmission Powertrain, pp. 930-935

Mrochen, Michael A. — Univ. of Stuttgart, Germany
Sawodny, Oliver — Univ. of Stuttgart

More and more modern passenger cars use hybrid electric propulsion sources that combine the advantages of internal combustion engines (ICE) and electric machines (EM). There exists a wide variety of different hybrid electric vehicle topologies and realizations. To compete in this market, Magna Transmission Systems has presented the 7HDT300, a hybridized dual-clutch transmission (DCT). In this transmission, an EM is connected side-by-side to one of the two sub-transmissions via a gear reduction set. This allows a considerably smaller highspeed EM, which is lighter and more cost-effective, without affecting the powertrain length. Furthermore, the EM and the ICE can use different gears, so that both can work within their optimal efficiency range.

This contribution introduces a complete model of a hybrid DCT using a flexible multibody approach for the drivetrain, including the clutch actuation and all torques occurring in the powertrain, based on physical models. With this, the most common driving use cases can be simulated, e.g. acceleration from stillstand, driving with either the ICE or the EM, shifting gears, and starting the ICE with the EM using the clutch. Especially the latter scenario obliges an accurate model of the ICE, including the starting behavior and extending beyond the often used engine maps, which are only valid for a running engine. With a suitable set of parameters, the proposed model shows a physically reasonable behavior, making it possible to perform simulations of real vehicles. Moreover, the model is the basis for simplifications towards a model-based control design.

10:25-10:45 SaM4.3

Optimizing Design of Powertrain Transmission Ratio of Heavy Duty Truck, pp. 936-941

Peng, Meichun — Guangdong Univ. of Tech
Lin, Junyan — Guangdong Univ. of Tech
Liu, Xuqi — Guangdong Univ. of Tech

This paper optimized the powertrain transmission ratio of a heavy duty truck for saving energy. With 142659 sets of actual road operation data of vehicle including speed, fuel consumption, etc., a typical vehicle driving cycle HTDC-1800 was constructed, and it was applied into a truck performance simulation model to study the effect of transmission gear ratio on the fuel consumption. With the powertrain gear ratios as design parameters, fuel consumption as optimization objective, Multi-Island Genetic Algorithm was used to optimize powertrain gear ratios. The optimal scheme of powertrain transmission ratios was obtained by joint simulation with coupling the vehicle performance simulation model and the optimization model, and the vehicle's fuel consumption decreased by 8.19% without apparent decline of dynamic performance.

10:45-11:05 SaM4.4

Optimization of CVT Efficiency Based on Clamping Force Control, pp. 942-947

Wu, Guang-bin — Jilin Univ
Lu, Yan-hui — Jilin Univ
Xu, Xiao-wei — Jilin Univ

In order to improve the transmission efficiency of CVT under various

driving conditions, this paper proposes an integrated control strategy for optimization of clamping force in pulley. The strategy is based on driving conditions identification and slip trend observer. A Simulink-AMESim co-simulation model is established. Simulation conditions include the acceleration conditions, uphill road conditions, and urban + suburban circle conditions, simulation results show that the new strategy can optimize the transmission efficiency of CVT and therefore increase the fuel efficiency of the vehicle.

11:05-11:25 SaM4.5

Launch Coordination Control Based on Twin-Clutch Torque Distribution for DCT Vehicle, pp. 948-953

Jiang, Zijiao — Jilin Univ
Liu, Qifang — Jilin Univ
Dong, Shiying — Jilin Univ
Chen, Hong — Jilin Univ. Campus NanLing

For Dual Clutch Transmission (DCT) vehicle, this study provides a launch control method that coordinates the transmission torque of twin clutches. The launching process is divided into 2 stages. For the first stage, the total torque is obtained by using Model Predictive Control (MPC) method, and total torque is distributed to two clutches based on principle of equal slipping work. For the second stage, a torque distribution rule is given to allow launching clutch engaged and separating clutch disengaged. Then, stability of MPC controller is discussed. Compared with single clutch launch PID controller, the simulation results show that the proposed MPC launch controller could greatly shorten the time of launching process, decrease slipping work, avoid possible power coupling and power cycling.

11:25-11:45 SaM4.6

Shift Quality Amelioration of Electric Vehicles with AMT by Speed Regulation, pp. 954-961

Pang, Bo — Jilin Univ
Hong, Jinlong — Jilin Univ
Gao, Bingzhao — Jilin Univ
Chen, Hong — Jilin Univ. Campus NanLing
Li, Zhanjiang — Nanjing Yue Bo Automotive Electronics Co., Ltd

Due to torque interruption and clutch friction of Automated Manual Transmissions (AMT) during gear shift, the shift quality is not as positive as other kinds of transmissions, several ways to improve shift quality such as reduce shift time have been researched. During the gear shift process in AMT, new gear speed needs to be regulated as gear ratio changes. In this paper, the research topic is concerning gear shift process of an AMT of electric vehicles, the influence of the speed difference between new gear and synchronizer on gear shift time is studied. Powertrain model of the electric vehicles with AMT is built in ADAMS and several simulations are conducted. Simulation results demonstrate that by controlling the speed difference between new gear and synchronizer in a positive small range from 0rpm to +10rpm with the shift force at 200N, shifting synchronizer can be engaged in a short time. In addition, results also demonstrate that within small speed difference range, the existence of synchronizer ring has little effect on gear shift performance, which illustrates that the structure of AMT on electric vehicles can be simplified.

SaM5 The 2nd Meeting Room In North Zone

Autonomous Vehicle and Control (Regular session)

Chair: Yu, Zhuoping — Tongji Univ
Co-Chair: Zhang, Lei — Univ. of Tech. Sydney

09:45-10:05 SaM5.1

Research of the Steering Stability for an Eight In-Wheel Motor Drive Vehicle, pp. 962-967

Yu, Haibo — China Electric Power Res. Inst. Beijing
Chen, Yong — Beijing Inst. of Tech
Li, Helong — China Electric Power Res. Inst. Beijing
Huang, Kanglun — Beijing Inst. of Tech

In this paper, the two degree of freedom reference model of a multi axis independent driving vehicle is established to solve the problem of control and stability of a multi axis independent steering vehicle. The steady state response of the vehicle under the step input of the four axis steering angle is analyzed. Finally, the simulation analysis is carried out for the steering mode based on the zero centroid side angle. The analysis results show the correctness of the analysis. At the same time, the factors affecting the stability of the vehicle was selected and reference state value was also given.

10:05-10:25 SaM5.2

Design of Unmanned Park Vehicle Decision-Making System Based on Uncertainty Information (I), pp. 968-973

Yu, Zhuoping — Tongji Univ
Chen, Wenbo — Tongji Univ
Zhu, Chenyu — Tongji Univ

In this paper, the behavior decision method of low-speed unmanned industry park vehicle is mainly based on finite state machine, whose core is to determine the boundary conditions of state transition, to guide the finite state machine to switch the correct behavior mode and output correct target behavior. An uncertain behavioral decision making method is proposed in this paper. The confidence of the vehicle's current state relative to the boundary condition of the behavior decision is taken as the judgment basis of the decision. The Bayesian reasoning method and the DS evidence theory are integrated to solve the problem that the boundary of the finite state machine is too clear and the behavior mode switching is more mechanical to a certain extent.

10:25-10:45 SaM5.3

Study on Dynamic Characteristics and Control Algorithm Design for Fuel Metering Valve of High-Pressure Pump, pp. 974-979

Lu, Yi — Beijing Inst. of Tech
Zuo, Zhe — Beijing Inst. of Tech
Zhao, Changlu — Beijing Inst. of Tech
Zhang, Fujun — Beijing Inst. of Tech
Du, Meng — Beijing Inst. of Tech

High rail pressure and multiple injections are crucial to improve diesel engine performance in terms of fuel efficiency and exhaust emission. As a drawback, rail pressure oscillations and complex pressure-wave propagation phenomena have impact on the control accuracy and response speed. Fuel metering valve, installed on the inlet of high-pressure pump, is the main mechanical actuator to adjust the rail pressure value. In this paper, the co-simulation model was established to investigate the dynamic process which is divided into three phases. The motion dead zones of the valve member and spring preload are the main factors for non-linearity working zone of the fuel metering valve. Therefore, the corresponding segmented control algorithm is designed to adjust the rail pressure based on the fuel flow rate and ideally realize synchronization of the control signals and rail pressure response.

10:45-11:05 SaM5.4

GPS/INS/Odometer/DR Integrated Navigation System Aided with Vehicular Dynamic Characteristics for Autonomous Vehicle Application (I), pp. 980-986

Yu, Zhuoping — Tongji Univ

Hu, Yingjie Tongji Univ
Huang, Jiamei Tongji Univ

Accurate positioning and orientation are of vital importance for autonomous vehicles. Global Navigation System(GPS) and Inertial Navigation System(INS) are two popular types of navigation systems and are usually integrated together to overcome each other's defects. Based on the GPS/INS system, many other elements are introduced into it for accuracy improvement such as odometer, kinematic or dynamic models and so forth. This paper utilizes the dynamic characteristics of vehicles by constructing tire dynamic model and vehicle dynamic model. In this way, an integrated navigation system of GPS/INS/Odometer/DR(dead reckoning) is established by means of extended Kalman Filter(EKF), a practical and popular channel for data fusion. Field test is conducted to prove the algorithm feasible and valid. Test results indicate that this proposed GPS/INS/Odometer/DR integrated navigation system is able to provide accurate position and orientation information thus qualified for autonomous vehicles navigation. The test of GPS signal outage is also held and experiment results show that the proposed algorithm can also remain stable and reliable in case of GPS signal unavailability.

11:05-11:25 SaM5.5

Acceleration Slip Regulation for Four-Wheel-Independently-Actuated Electric Vehicles Based on Road Identification through the Fuzzy Logic (I), pp. 987-992

Ding, Xiaolin Beijing Inst. of Tech
Zhang, Lei Beijing Inst. of Tech
Wang, Zhenpo Beijing Inst. of Tech
Liu, Peng Beijing Inst. of Tech

In this paper, a novel method is proposed for tire-road adhesion coefficient estimation based on the fuzzy logic theory for a four-wheel-independently-actuated electric vehicle (FWIA EV). In the meantime, the vehicle velocity is estimated by the unscented Kalman filter method, which provides the foundation for real-time slip ratio calculation. A PID controller is further synthesized for Acceleration Slip Regulation (ASR) to derive the output torque of each in-wheel motor through feeding the error between the real-time slip ratio and the optimal slip ratio based on road identification. Finally, the effectiveness of the proposed scheme is validated under opposite roads with full acceleration in simulation, and the results show that the proposed ASR scheme is capable of improving the driving performance of the FWIA EV.

11:25-11:45 SaM5.6

Differential Flatness-Based Robust Control of Self-Balanced Robots, pp. 993-998

Liang, Dingkun Inst. of Robotics and Automatic Information Systems (IRAIS)
Sun, Ning Nankai Univ
Wu, Yiming Nankai Univ
Fang, Yongchun Nankai Univ

Underactuated self-balanced robots (SBRs) can be used to implement various tasks. However, with complicated system dynamics and existing external disturbances, the control issue of SBRs is still open and challenging. In order to deal with such problems, by constructing flat outputs, this paper proposes an active disturbance rejection control (ADRC) method for SBRs both on the horizontal plane and the inclined plane, which achieves control objectives of tracking reference signals and can reject perturbations online. Additionally, the integral algebraic estimation and the generalized proportional integral (GPI) methods are applied. Finally, to verify the effectiveness of the proposed controller, numerical simulation results are provided.

SaM6 The 3rd Meeting Room In South Zone

Advanced Modeling and Control of Vehicle Ride Dynamics (Invited session)

Chair: Liu, Zhiyuan Harbin Inst. of Tech
Co-Chair: Li, Jie Jilin Univ
Organizer: Liu, Zhiyuan Harbin Inst. of Tech
Organizer: Li, Jie Jilin Univ

09:45-10:05 SaM6.1

Adaptive Event-Triggered Control for Vehicle Active Suspension Systems with State Constraints (I), pp. 999-1004

Pan, Huihui Harbin Inst. of Tech
Sun, Weichao Harbin Inst. of Tech
Zhang, Jinhua Harbin Inst. of Tech
Yan, Shuai Harbin Inst. of Tech
Lin, Weiyang Harbin Inst. of Tech

To reduce the communication burden between the controller and the actuator, this paper proposes an adaptive event-triggered control method for nonlinear vehicle active suspension systems with state constraints. Without determining a priori knowledge of the control direction, the presented approach can be implemented based on the constrained adaptive technique for simultaneously addressing the physical state limitations in the presence of parametric uncertainties and compensating the measurement error caused by the event-triggering mechanism. A Lyapunov stability proof guarantees that the closed-loop suspension system is stable, and the suspension movement limitation is not violated. A designed example is given to illustrate the effectiveness of the presented controller for improving the vehicle ride performance.

10:05-10:25 SaM6.2

Distributed Model Predictive Control and Implementation for Vehicle Active Suspensions (I), pp. 1005-1010

Shao, Siqi Harbin Inst. of Tech
Zhou, Hongliang Harbin Inst. of Tech
Liu, Haifeng Harbin Inst. of Tech

This paper proposes a distributed model predictive control (DMPC) method for a half-vehicle system with active suspensions. First, the half-vehicle system is divided into three subsystems to reduce the system dimension. Considering the distribution characteristics of suspension control systems, a DMPC controller is designed for each suspension subsystem in order to inhibit the vehicle vertical and pitch motion. To evaluate the proposed control system, controllers with low cost micro-control units (MCU) are implemented, where a fast MPC method for real-time optimization based on continuation/general minimum residual (C/GMRES) method is realized and in-vehicle network FlexRay is used to exchange control information among these controllers. Finally, the implementation of DMPC controllers in MCUs is finished and the results show that vehicle comfortability can be improved by the proposed controllers.

10:25-10:45 SaM6.3

Piecewise Affine Hinf Control of Half-Car Magneto-Rheological Suspension Systems (I), pp. 1011-1016

Liu, Zhiyuan Harbin Inst. of Tech
Wu, Jian Harbin Inst. of Tech

This paper presents a novel controller design for half-car magneto-rheological (MR) suspension systems. By introducing a piecewise approximation model, the nonlinear constraints of MR dampers are transformed into piecewise constant constraints. Further, by defining a piecewise affine control law, the attenuation of pitch and heave responses are realized by satisfying a given Hinf index. The control gains are derived through linear-matrix-inequality (LMI) optimization. Simulations under random and impact roads

have verified the effectiveness of proposed controller on performance improvement and constraint satisfaction.

10:45-11:05 SaM6.4

Suspension Hybrid Control for In-Wheel Motor Driven Electric Vehicle with Dynamic Vibration Absorbing Structures (I), pp. 1017-1022

Qin, Yechen — Beijing Inst. of Tech
He, Chenchen — Beijing Inst. of Tech
Ding, Peng — Beijing Inst. of Tech
Mingming, Dong — Beijing Inst. of Tech
Huang, Yanjun — Univ. of Waterloo

This paper presents a hybrid control strategy for suspension of the in-wheel motor(IWM) driven electric vehicle (EV) to improve vehicle ride comfort and reduce IWM vibration. A quarter vehicle model with the dynamic vibration absorbing structure (DVAS) is first developed. Different from the traditional suspension system, the DVAS uses an extra spring-damper system to achieve vibration reduction. The dynamics and boundary models for two commercially available and controllable dampers are then presented. Both dampers in the suspension and the DVAS are used to allocate the hybrid control force synthesized depend on the system responses. Simulation results for excitations of both random road and bump input are finally analyzed, and the proposed hybrid controller can simultaneously improve ride comfort and reduce IWM vibration compared to the traditional suspension system.

11:05-11:25 SaM6.5

ESO-Based Double Closed-Loop Servo Control for Automobile Electronic Throttle, pp. 1023-1027

Xue, Jiaqi — Yanshan Univ
Jiao, Xiaohong — Yanshan Univ
Sun, Zitao — Yanshan Univ

A kind of double closed-loop servo control strategy is presented in this paper to realize accurate and fast position tracking of throttle valve for the automobile electronic throttle control system (ETCS). The control structure includes an extended state observer (ESO) compensating for the total disturbances resulted from nonlinearities of friction and return springs and uncertainties of some physical parameters, and two PI-type controllers with disturbance compensators of the outer position loop and the inner current loop. The proposed scheme is featured by transforming the control gains determination for the two PID-type controllers into the derivation of state feedback gains. And the transformation is carried on by means of the augmented deviation equations constructed by the ESO-estimated unmeasurable current and angular velocity of throttle. And control parameters of the two feedback loop controllers and ESO can be instructively determined by solving the linear matrix inequalities (LMIs) obtained from the Lyapunov stability analysis of the whole closed-loop system. The feasibility of the proposed strategy is validated in both simulation and hardware-in-the loop (HIL) test platform.

11:25-11:45 SaM6.6

An Optimal Driving Strategy for the Ride Comfort Performance of Intelligent Vehicles on Uneven Roads (I), pp. 1028-1033

Sun, Jianing — Harbin Inst. of Tech
Liu, Zhiyuan — Harbin Inst. of Tech
Wu, Jian — Harbin Inst. of Tech

This paper proposes an optimal driving strategy to improve the ride comfort performance of intelligent vehicles, which is different from the general researches that focus on the driving safety. Firstly, based on the establishment of a 7-DOF vehicle model and a road excitation model, the relationship between vehicle velocity and the comfort index is analyzed and a non-monotonic polynomial is presented. Then, a velocity control requirement considering driving performance and comfort performance is constructed and transformed into a multi-objective optimization problem. By using Pareto optimization theory, a set of Pareto optimal solutions is obtained. Finally, to choose a velocity from the Pareto optimal set, a strategy considering the subjective and objective comfort indexes from ISO2631 is given. This strategy can be applied to velocity planning of intelligent vehicles on uneven roads. The simulation results show that the proposed strategy is effective and feasible.

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