Recent works on automotive control systems (invited session)

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AbstractThis session aims at providing new results on modelling, control and estimation of automotive control systems to be part of Advanced Driver Assistance Systems or to equip Autonomous vehicles.

Keywords: Vehicle Dynamic Control, Semi-active suspension, Steering control,Human-Vehicle Interaction, longitudinal and lateral control, autonomous vehicles....

1. SESSION TOPIC, GOALS AND COHESION

Over the past few years, automotive engineering has been characterized by rapid growth in active systems. Many research works have therefore been devoted to the control of such active subsystems, as braking, steering or suspension actuators. In particular the use of different actuators (braking, steering, suspension ...) allow to tackle emergency situations such as rollover, too large lateral and yaw accelerations, slipping .... Moreover the improvement of the interaction in between the driver and car capabilities have been the objectives of many recent research works concerning driver assistance system.

Such research works are now of paramount importance for the development of autonomous vehicles for which the use of advanced control methods using several actuators (braking, steering, suspension ...) will allow to handle emergency situations and avoid accidents.

Active safety and driver assistance systems are intensively analyzed research and development area that covers a wide range of topics. These topics are also reflected by the papers of the session.

All the papers are concerned with the safety and comfort aspects of the smart ground vehicles .

2. PAPERS OF THE SESSION

2.1 Recent Research Activites on Automotive Control at DLR Institute System Dynamics and Control - An Overview

Authors: *Authors*: Jonathan Brembeck, Daniel Baumgartner, Caspar Bieri, Tilman Bunte, Jonas Mirwald, Andreas Pfeiffer, Ricardo de Castro, Julian Ruggaber, Jakub Tobolar, Johannes Ultsch, Christoph Winter, Johann Bals.
Abstract: Safety, comfort, and responsible use of natural resources are in the focus of the work regarding road vehicles in automotive research group at the DLR (German Aerospace Center) Institute for System Dynamics and Control. In this field, the research topics of energy management, vehicle dynamics and vehicle intelligence are addressed. These activities will, in particular, exploit the opportunities offered by digitalization, automation, and electro-mobility in order to decrease the tension between mobility demands and its harmful collateral effects. The development of modular, mechatronic, and highly integrated chassis and propulsion systems benefits from a holistic approach based on common vehicle concepts. This idea serves as a framework across the DLR for the coordinated development of concepts, methods, and technologies in the core funded Next Generation Car (NGC) project.

2.2 Control of a Semi-Active Suspension for In-Wheel Motors PowerTrains

Authors: Jorge de Jesus Lozoya Santos, Mauricio Anaya Martinez, Ricardo Ramirez Mendoza, Ruben Morales Menendez.
Abstract: In this work, four different semi-active controllers for quarter of vehicle (QoV) are evaluated and compared when used in electric vehicles with in-wheel motor configuration considering a magnetorheological (MR) damper as semi-active device and a switched reluctance motor (SRM). The QoV vertical dynamics is analyzed and then the effectiveness of the control strategies are evaluated in time and frequency domain. A comparison in the frequency domain responses between ICE and in-wheel QoV's with and without the unbalanced vertical force (Fv) generated by SRM wallop is presented and analyzed

2.3 A multi-modes semi-active suspension control strategy for RCZ vehicle

Authors: Ghazi BEL HAJ FREJ, Xavier MOREAU, Emna HAMROUNI Andre BENINE-NETO, Vincent HERNETTE.
Abstract: In this paper, a new semi-active suspension control strategy is proposed for Peugeot RCZ vehicle.

The aim of this study is to automate transition between the two existing modes of suspension based on nonlinear damping laws and using a variable damper. By minimizing a quadratic gap between a control target and the control actuation force issued from each mode, a decision strategy is defined and a suspension mode is selected, so that the variable damper can achieve it by controlling the actuation force. The used control target is synthesized using CRONE-Skyhook approach. Simulation results show that the requirements in terms of passenger comfort and vehicle stability are reached applying the proposed control strategy.

2.4 Improvement of low-frequency comfort through the design of CRONE-SkyHook suspension systems

Authors: Emna HAMROUNI, Ghazi BEL HAJ FREJ, Xavier MOREAU, Andre BENINE-NETO and Vincent HERNETTE.
Abstract - This paper deals with the vehicle dynamics control and focuses on Global Suspension Control (GSC). The aim of this article is to improve low-frequency comfort, defined in the frequency range [0 ;5] Hz, of a semi-active suspension system. To do, an analysis and synthesis approach is proposed on a functional scale. A target behaviour of the equivalent open-loop, seen from the angle of isolation vibration, is generalized using CRONE-SkyHook (CSH) approach. The controller implemented on the validation model is therefore deduced. Simulation results show that requirements in terms of body handling under road solicitations and filtering.

2.5 Frequency-shaping observer-based controller design for actuator degradation : Application to suspension system

Authors: Manh-Hung DO, Damien Koenig, Didier Theilliol.
Abstract: The main contribution of this paper is a methodology, derived from H2 cost functional, Parseval's Theorem in controller design and the principle of unknown input observer, for the estimation and accommodation of polynomial actuator degradation. In this design, the observer-based controller, integrated with a frequency-shaping filter and a state-feedback compensator, attenuates the disturbance influence on observer estimation and maintains the system stability. Furthermore, due to its simplicity, industrial engineers and readers can easily apply the proposed method to health maintenance system. Finally, an application to suspension system is illustrated to highlight the performance of the proposed method.

2.6 Integrated semi-active suspension and cruise control design based on look-ahead road information

Authors: Hakan Basargan, Andras Mihaly, Peter Gaspar, Olivier Sename
Abstract: Semi-active suspension control and vehicle cruise control systems have already been developed by researchers and adapted by automotive companies. Most of these systems react on actual road irregularities and terrain characteristics, and the control for each subsystem is designed separately. However, since oncoming road conditions can be known by using historic road information and GPS navigation system, the paper introduces a method to build in look-ahead road data in the control of the adaptive semi-active suspension, moreover, design the vehicle velocity for the cruise controller considering comfort and energy efficiency at the same time. The operation of the presented integrated suspension and velocity control system is validated by a real data simulation in TruckSim environment

2.7 Fault tolerant velocity control of an urban autonomous vehicle based on a switching strategy

Authors: RUHNKE Melodie, MOREAU Xavier, BENINE-NETO Andre, MOZE Mathieu, AIOUN Francois, GUILLEMARD Franck, RIZZO Audrey.
*Abstract:*This paper presents a methodology of switching control law following a fault detection of a controller on a longitudinal speed regulation. This method consists on designing a dynamic parity space to detect a fault on a PI controller. The latter is supposed to regulate the longitudinal speed. Then a supervisor is put in place in order to calculate a residue, analyze it and generate a signal to switch from the PI controller to the CRONE and so ensure the speed regulation despite the fault.

2.8 LPV control for autonomous vehicles using a machine learning based tire pressure estimation

Authors: Daniel Fenyes, Tamas Hegedus, Balazs Nemeth, Peter Gaspar, Olivier Sename.
Abstract: The paper proposes a Linear Parameter-Varying (LPV) control design for automated vehicles, in which the results of the big data-based analysis for tire pressure estimation is incorporated. The estimation algorithm uses vehicle dynamic signals, which are available from the on-board sensors. The pressure of the tire has a high importance of the tire-road contact, because it influences the characteristics of the longitudinal and lateral forces. During the operation of the vehicles the pressures of the tires may decrease over time, which can result in performance degradation or the loss of the controllability. In the paper a novel data-driven pressure estimation method is provided, whose result is used in the LPV-based lateral control design as a scheduling parameter. Finally, a comprehensive simulation with CarMaker software is presented, which shows the efficiency of the proposed control algorithm.

2.9 A first approach for a passenger-centered behavior on driverless vehicles

Authors: David Gonzalez Bautista, Francisco Navas, Imane Mahtout, Vicente Milanes
Abstract: Driverless shuttles are becoming one of the most promising applications of automated vehicle technologies in the short term. For a real system deployment, passenger?s acceptance on the shuttle performance will play a key role. This paper presents a passenger-centered control algorithm design for increasing passenger?s ride quality. Controllers with different performance but keeping the same robustness are developed for lane-level autonomous navigation. The whole solution has been implemented and tested in a real vehicle, using a roundabout as use-case scenario, providing encouraging

2.10 Trajectory reference generation coupled with a guidance control for autonomous vehicle lane change maneuver

Authors: Manel Ammour, Rodolfo Orjuela, Michel Basset.
Abstract: One of the expected tasks that autonomous vehicle may do is driving on highway which makes performing lane change maneuvers inevitable. In order to ensure the safety of the lane change, the contingency planning approach must generate smooth and feasible local trajectory adequate for overtaking or collision avoidance applications. This paper presents a method to carry out a lane change maneuver based on a sigmoid function trajectory. The main contribution of this paper is to provide an envelope of the set of the feasible parametrized sigmoid functions based on vehicle dynamics and geometric contraints. The few parameters used in the trajectory adjustment make the lane change maneuver safe, comfortable and applicable in real-time. The proposed lateral controller switches between attenuating the lateral error and the orientation error to better track the desired reference trajectory. CarMaker simulation results show the applicability of the proposed approach.

2.11 Optimal LPV-based control and estimation for autonomous vehicles

Authors: E. Alcala, M. Facerias, V. Puig
Abstract: This article presents a proposal to the problem of designing advanced control and estimation techniques to give solution to the autonomous driving guidance. In particular, this work takes advantage of the properties of polytopic LPV systems and predictive optimal control to guide the vehicle along a planned trajectory. Linear Parameter Varying (LPV) theory is used to model the dynamics of the vehicle and implement an LPVModel Predictive Controller (LPV-MPC) that can be computed online with reduced computational cost. Furthermore, the LPV framework is used to design an optimal observer that estimates vehicle variables that cannot be measured. The control and estimation scheme is validated in simulation using the Robotic Operating System (ROS) framework where its effectiveness is demonstrated.

2.12 Vehicle Control in Highway Traffic by Using Reinforcement Learning and Microscopic Traffic Simulation

Authors: Laszlo Szoke, Szilard Aradi, Tamas Becsi, Peter Gaspar
Abstract:

The paper presents a simple yet powerful and intelligent driver agent, designed to operate in a preset highway situation using Policy Gradient Reinforcement Learning (RL) agent. The goal is to navigate safely in dense highway traffic and proceed through the defined length with the shortest time possible. The algorithm uses a dense neural network as a function approximator for the agent with discrete action space on the control level, e.g., acceleration and steering. The developed simulation environment uses the open-source traffic simulator called Simulation of Urban MObility (SUMO), integrated with an interface, to interact with the agent in real-time. With this tool, numerous driving and highway situations can be created and fed to the agent from which it can learn. The environment opens the opportunity to randomize and customize the other road user' behavior. Thus the experience can be more diverse, and thus the representation becomes more general. The article describes the modeling environment, the details on the learning agent, and the rewarding scheme. After evaluating the experiences gained from the training, some ideas for optimization and further development goals are also proposed.

2.13 Fault-Tolerant Distributed and Switchable PI Slip Control Architecture in Four In-Wheel Motor Drive Electric Vehicles

Authors: Gerardo Amato and Riccardo Marino.
Abstract: A fault-tolerant feedback architecture is presented and simulated for chassis motion control of both longitudinal and lateral dynamics in Four In-Wheel Motors (4-IWMs) drive Electric Vehicles (EVs), in the presence of mechanical failures. The control architecture is capable of a quick Fault Detection and Isolation (FDI) by making a sensor fusion between the measured chassis-acceleration vector angle and its estimate through distributed torque loads estimation. The fault isolation is allowed by comparing online left and right torque load estimates. The proposed architecture can switch smoothly from 4-IWMs to 2- IWMs configurations, by excluding the whole faulted axle to preserve the torque balancing.

2.14 Vehicle odometry model identification taking into account the dynamic/vertical load change

Authors: Mate Fazekas, Balazs Nemeth, Peter Gaspar, Olivier Sename.
Abstract: The article proposes an automatic parameter identification algorithm for vehicle model from real measurements of onboard sensors. The motivation of the paper is to improve the localization in critic circumstances. For example, when the GNSS signals are unavailable, or when the vision based methods are incorrect due to the lack of enough feature, furthermore, when IMU based methods are useless due to the lack of frequent accelerations. In these situations the wheel encoder based odometry can be an appropriate choice for pose estimation, however this method suffers from parameter uncertainty. The proposed method combines the Kalman-filter and least square techniques in an iterative loop. The estimation result is verified by real test of a compact car. The results are compared with the nominal setting, which should be used if there is not any estimation

2.15 Human-Vehicle Interaction Analysis: Energy Performances

Authors: Andres Campos Ferreira, Jorge de Jesus Lozoya Santos, Ricardo Ramirez Mendoza, Ruben Morales Menendez.
Abstract: One of the most used machines around the world are the cars. It is the main way of transporting and has provided great benefits. Nevertheless, the wrong use and bad behaviour from the drivers have lead to high rate of accidents. Since the last decade several researches have been focused its efforts on improving the vehicle subsystems in order to provide more security and comfort to the passengers. Nevertheless, most the analysis have not

considered the human and the vehicle as a whole system. This paper proposes a work in progress framework for the study of the human-vehicle interaction by obtaining energy indexes of driver and vehicle, as well as the driving style during a trip. Besides, a Principal Component Analysis was done to define the main parameters that provides more information to correlate the variables from the driver and the car.

2.16 Optimal Closed Loop Input Signal for Internal Model Control

Authors: Jianwang Hong, Ricardo A. RamÃrez-Mendoza, Ruben Morales-Menendez, Jorge de-J Lozoya-Santos, Hugo G. Gonzalez-Hernandez
Abstract: The purpose of this paper is to design an optimal input signal for internal model control. In order to design the optimal input signal in internal model control, we establish the equivalence between internal model control and standard closed-loop control and we consider the uncertainty between the process model, disturb model and the controller. The identified model performance index is associated to the mean square of the output error. An optimization problem with constrained condition in according to the optimal input signal is stated. Finally, the efficiency and feasibility of the proposed strategy is confirmed by an example.