Ph D position 2020:

Control of autonomous vehicles using Linear Parameter Varying approaches

Supervisors : Olivier Sename : olivier.sename@grenoble-inp.fr
Vicenç Puig: vicenc.puig@upc.edu
Web : www.gipsa-lab.grenoble-inp.fr/

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CONTEXT
This thesis is part of the project SARAH (SAfe and Robust Autonomous veHicles), co-supported by the UPC and UGA.

It concerns the contribution of advanced control methodologies to participate in the technological development of autonomous cars (levels 3 and 4). Indeed Automated vehicles will enhance road safety, increase highway capacity, reduce carbon emission, and make transportation more accessible to disable and older people.

While some recent works have been obtained using robust control methods, there remain unsolved problems in particular during emergency situations due to the intensification of traffic, the variability of road user types, weather conditions or driver error. This requires to handle the coupling between several subsystems (as the longitudinal and lateral ones), which becomes even more difficult in the presence of some sensor / actuator failures that may lead to an important loss of performances/stability.

OBJECTIVES
This thesis work aims at developing and validating (longitudinal/lateral) integrated LPV control methods of several subsystems and actuators (power/braking, steering, suspension, ...), to ensure the efficiency, robustness and reliability of the autonomous car, considering several issues as:

- The integrated design of algorithms for the detection of malfunction and control reconfiguration
- Taking into account the characteristics of the driver, the vehicle, and their interactions, especially in dangerous driving situations
- The interaction between various active safety subsystems, in particular to ensure road safety in an environment integrating different types of vehicles and users
- The interaction with the road infrastructure

To take this aspect into account, observation and control methods will be approached using robust control approaches for Linear Parameter Varying Systems to account for the variations of environmental conditions (road condition, driver, sensor / actuator failures ...), nonlinearities of the vehicle, but also adaptive real-time performance.
METHODOLOGY

The main issue is to develop integrated control laws, multivariable, requiring the cooperation of several subsystems and actuators (power/braking, steering, suspension,...), using several sensors (Accelerometers, GPS, Radar/Lidar, Camera...) guaranteeing efficiency and safety, in particular in the face of critical situations. The overall scheme we are interested in is as follows:

Some of the key innovative works shall concern:

- **LPV modelling** of autonomous cars, for a wide range of speeds, subject to environment uncertainties (as undesirable effects of the driver’s actions on the vehicle dynamics) and to faults (on the system and/or components).

- **Design of estimation algorithm (observers)** solving the state/fault observation problem in order to “diagnose” the vehicle state and be able to ensure safe future vehicle trajectories.

- **Design of LPV reconfigurable controller** that will handle the variations of environmental conditions (road condition, driver, other vehicles ...) and the nonlinearities of the vehicle model, but also able to adapt to fault estimations and to the interaction with the driver actions and with other users, in order to reconfigure the control on-line and ensure the car safety.

- **Performance assessment (in simulation and experimental tests)** of the proposed algorithms for several driving situations of an autonomous vehicle, using realistic full car vehicle models available in GIPSA-lab [Fergani16] and using the scaled platform available in UPC [Alcala20]. It could be also studied, as explained later, in collaboration with the Academy of Sciences of Budapest (Using the available automated Nissan Leaf) and/or with Renault using the automated Renault Zoe.

During the thesis, other collaboration may be developed with other partners as the Academy of Science in Budapest, the CRAN in Nancy and some industrial partners as Renault.

SCHEDULE

The study will be decomposed in the following agenda:

**Year 1**

- Review of the state of the art on: LPV systems, LPV observers and control design, Fault diagnosis, FTC, control architectures for automated vehicles, *Cooperative Adaptive Cruise Control* (for speed regulation) and *Steering control* (for lane keeping and obstacle avoidance)

- Study on Vehicle Dynamic Modelling and proposition of an LPV model
- Study of existing longitudinal and lateral control strategies. First integration of both control functions (designed independently) and simulation in closed-loop on the proposed LPV model
- Write a first conference publication

**Year 2**
- Design of algorithm for the monitoring critical situations: LPV observer design for state estimation, also for fault estimation, and comparison with Kalman Filter approach using experimental data
- Develop a first LPV control of the steering/braking scheduled by the information coming from the estimation of critical situations (as sensor/actuators faults or monitored states)
- First validation in simulation using full car realistic models available in GIPSA-lab
- Validation using experiments (UPC platform) of the first control approach
- Write conference and journal papers

**Year 3**
- Refine the LPV controller adding some control objectives of the suspension systems and accounting for variations of environmental conditions (road condition, driver, (to reach a safe global chassis control)
- Validation in simulation for the complete structure and in experimental conditions for a specific allowed scenario
- Write the PhD thesis dissertation and journal papers

**REFERENCES**
- Eugenio Alcalá, Vicenç Puig, Joseba Quevedo, Ugo Rosolia, Autonomous racing using Linear Parameter Varying-Model Predictive Control (LPV-MPC), Control Engineering Practice, Volume 95, 2020,
- M. M. Seron, J. A. De Donà, “Robust fault estimation and compensation for LPV systems under actuator and sensor faults”, Automatica, Volume 52, February 2015, Pages 294-301

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- CV with contact details
- Bachelor and master transcripts (including list of courses with corresponding grades) for all the university years
- A summary of (or an e-link to) your master thesis
- Name and email of two references