Monday September 12

9h – 10h  J.Bokor/O.Sename/P.Gaspar
Introduction and Motivation

10h- 11h  M.Lovera
LPV modelling and identification (Part I)

11h-11h30 Coffee break

11h30- 12h30 M.Lovera
LPV modelling and identification (Part II)

Abstract (LPV modelling and identification) : In recent years there has been a significant research effort in the application of advanced modelling and identification techniques to control design. In spite of this, there is a strong need to investigate new approaches for dealing with the complexity and the increasingly stringent specifications arising in advanced applications. The lecture will first provide a general overview of the state-of-the-art in the fields of LPV modelling (i.e., analytical methods for the derivation of LPV models from nonlinear systems) and identification (i.e., experimental methods for the derivation of LPV models directly from data), with the objective of revealing the synergies between the two research fields, and will subsequently present some of the most recent results as well as some of the most challenging open problems arising in the development of methods and tools for advanced control-oriented modeling and identification.

12h30-14h Lunch

14h-15h30 J.Bokor, Z.Szabo
System analysis: a geometric approach

The mathematically dual concepts of (A,B)-invariance and (C,A)-invariance play an important role in the geometric theory of linear time invariant (LTI) systems. These concepts were used to study some fundamental problems of LTI control theory, such as disturbance decoupling (DDP), unknown input observer design, fault detection (FPRG). The nonlinear version of this geometrical approach is much more complex and deals with certain locally controlled or conditioned invariant distributions and codistributions. The aim of the lecture is to present an extension of these notions for the parameter-varying systems by introducing the notion of parameter-varying (A,B)-invariant, parameter-varying (C,A)-invariant, controllability and unobservability subspaces, and to give some algorithms to compute these subspaces if certain conditions are fulfilled. As an additional application example some special topics related to controllability of linear switching systems are presented.

15h30-16h00 Coffee Break

16h00–17h30 Z.Szabo, J.Bokor
Bimodal and Linear Switched Systems

The lecture considers some special topics related to controllability and stabilizability of linear switching systems. While providing a short overview on the most important facts related to the topic it is shown how fundamental role is played by the finite switching property in obtaining the controllability and stabilizability results. The (closed-loop) stabilizability problem of controlled linear switched systems is also revisited. It is shown that the completely controllable sampled switching system can be robustly stabilized (against disturbances and model uncertainties) with suitable linear feedbacks and a periodic switching strategy. A self contained treatment of the bimodal LTI problems is also provided pointing to the relevant structures of the problem. It is shown that for a certain class of bimodal systems controllability in case of closed-loop switching systems is equivalent with controllability of an open-loop switching system using nonnegative controls, i.e., to the controllability of a constrained open-loop switching system.
Tuesday September 13

8h30-9h30 Didier Henrion
Positive polynomial matrices for LPV controller synthesis Part I

9h30 -10h Coffee break

10h-11h00 Didier Henrion
Positive polynomial matrices for LPV controller synthesis (Part II)

Abstract (Positive polynomial matrices for LPV controller synthesis) : We review semidefinite programming formulations of multivariate polynomial matrix positivity conditions and we sketch potential applications for designing low-complexity LPV controllers.

11h15-12h15 J.Daafouz/ G. Millerioux
Observer design for polytopic and switched linear systems (Part I)

12h15-14h Lunch

14h-15h J.Daafouz/G. Millerioux
Observer design for polytopic and switched linear systems (Part II)

Abstract (Observer design for polytopic and switched linear systems): Polytopic systems are linear parameter varying systems defined by a convex combination of a finite number of extreme models. Switched linear systems can be considered as a particular class of LPV systems when the parameter take a finite number of possible values. The main purpose of this course is the design of observers for LPV and switched linear systems, including unknown input observers. Stability analysis of the observation error is carried out by means of parameter dependent Lyapunov functions in order to get less conservative results. Performance aspects such as decay rate, peak-to-peak, L2 gain and input to state stability will be discussed.

15h15-16h15 D. Henry
Structured fault detection filters under a H- gain constraint for LPV systems (Part I)

16h15-16h45 Coffee Break

16h45-17h45 D. Henry
Structured fault detection filters under a H- gain constraint for LPV systems (Part I)

Abstract (Structured fault detection filters under a H- gain constraint for LPV systems): The model-based residual generation problem is referred to the generation of structured diagnostic signals that have to be large during fault occurrences and insensitive to nuisance signals such as disturbances. The two commonly used approaches for designing Fault Detection and Isolation (FDI) schemes for LPV systems are the fault estimation approach and the residual generation approach. The fault estimation technique is convenient since the design problem can be formulated as a pure LPV H infinity filtering problem since the error between the fault estimates and the faults is minimized for all varying parameters. This allows to solve the problem using the techniques provided by the robust control community. Residual generation is fundamentally different from fault estimation because it can not be formulated in a minimization problem. In a residual generation problem the residuals have to be simultaneously robust to unknown inputs and sensitive to faults. This problem can be solved using both the H infinity norm and the so-called H- performance index. Because both these indices admit an L2 induced-norm definition, both LPV polytopic systems and the systems modelled in the LFR manner can be considered. Furthermore, a great advantage is that the procedure allows to take into account the controller actions within the design procedure and the residual structuring matrices are optimized as an integral part of the design. The goal is to obtain structured fault detection filters with enhanced fault transmission H- gain and large H infinity nuisance attenuation. The synthesis of the residual structuring and the filter state space matrices can be performed simultaneously using linear matrix inequality optimization techniques, allowing to obtain all fault detection filter optimal parameters, say, in "one shot". An investigation within the computational aspects demonstrate that the solution is structurally well-defined.
First the problem of comfort and handling improvements of a ground vehicle is treated through the joint control of the suspension and braking systems. Two H∞ gain-scheduled controllers are synthesized to achieve attitude and yaw performances according to the driving situation, observed through a simple vehicle monitor. The proposed strategy tackles the nonlinear tire braking force in an original way and meets the situation dependent objectives of the vehicle in a unified framework.

Then the coordination of active front steering and rear braking in a driver-assist system for vehicle yaw control is tackled in two different ways. In the first case, during normal driving situations, active steering control is involved for steerability enhancement. However, when the vehicle reaches the handling limits, both steering and braking collaborate together to ensure vehicle stability. The coordination of these actuators is achieved through a suitable gain scheduled LPV (Linear Parameter Varying) controller. The controller is synthesized within the LMI (Linear Matrix Inequalities) framework, while warranting H∞ performances. Judging the vehicle stability and handling limits is deduced from the phase-plane of the sideslip angle and its time derivative. In the second case, the vehicle dynamic stability controller (VDSC) aims at improving automotive vehicle yaw stability and lateral performances while taking into account the braking actuator limitations and use the steering actuator only if it is necessary. These objectives are treated in an original way by the synthesis of a parameter-dependent controller built in the LPV framework and by the solution of an LMI problem. The proposed solutions are coupled with a local ABS strategy to guarantee slip stability and make the solution complete. Nonlinear time and frequency domain simulations on a complex full vehicle model (which has been validated on a real car), subject to critical driving situations, show the efficiency and robustness of the proposed solutions.
Thursday September 15

8h30-9h30 J.Martinez
Multi-sensor fault-tolerant longitudinal control (Part I)
The aim of this talk is to present different multi-sensor schemes and discuss about their fault-tolerant properties. A brief state of the art in sensor failure modelling and multi-sensor schemes will be presented. Some insights about multi-actuator schemes and fault-tolerance will complete the talk.

9h45-10h45 J.Martinez
Multi-sensor fault-tolerant longitudinal control (Part II)
This presentation deals with the problem of obtaining fault-tolerant guarantees of a multi-sensor switching strategy for longitudinal control. The strategy selects, at each instant of time, the sensor (belonging to a collection of sensors) that provides the best closed loop performance, as measured by a control-performance criterion. It is assumed that each sensor has an associated feedback controller that has been designed such that the sensor-controller pair stabilises the closed loop system under normal operation conditions. Recent refinements for constructing ultimate-bound invariant sets allow obtaining less conservative fault-tolerant guarantees. Stability properties of the switching system under fault-free operation conditions and under presence of sensor failures will be presented.

10h45-11h45 Coffee Break

12h00-13h00 S.Savaresi
Virtual Reference Feedback Tuning (VRFT) for LPV systems: application to automotive control (Part I)

13h-14h30 Lunch

14h30-15h30 S.Savaresi
Virtual Reference Feedback Tuning (VRFT) for LPV systems: application to automotive control (Part II)

Abstract (Virtual Reference Feedback Tuning (VRFT) for LPV systems: application to automotive control): The Virtual Reference Feedback Tuning (VRFT) algorithm for LPV systems is a data-driven methodology that allows to directly design a fixed-order model-reference LPV controller without need of identifying and transforming the process. The proposed method is very well-suited in the automotive field, where dynamics are often too complex to describe in a control-oriented modeling perspective. In this work, two different test applications are considered: - pollutant emissions limitation and fuel saving in diesel engines; - braking control in two-wheeled vehicles

15h45-16h45 P.Gaspar /Z.Szabo
Design of a Two-Level Controller for Heavy Vehicles
The lecture focuses on a control design for a vehicle suspension system in which a balance between different performance demands is achieved. The starting point of the control design is a full-car model which contains nonlinear components, i.e. the dynamics of the dampers and springs and a nonlinear actuator dynamics. In order to handle the high complexity of the problem this paper proposes the design of a two-level controller of an active suspension system. The required control force is computed by applying a high-level controller, which is designed using a linear parameter varying (LPV) method. For the control design the model is augmented with weighting functions specified by the performance demands and the uncertainty assumptions. The actuator generating the necessary control force is modeled as a nonlinear system for which a low-level force-tracking controller is designed. To obtain the low-level controller a backstepping method is proposed. The operation of the controller is illustrated through a simulation example

16h45-17h15 Coffee Break

17h15-18h15 P.Gaspar /Z.Szabo
Observer-Based Brake Control for Railways
Since in a braking operation the shortest possible brake distance is required at all times an efficient and robust slip prevention control must be developed. The aim of the lecture is to present a control strategy based on an estimation method for the actual wheel-rail friction coefficient. A logic-based scheme that estimates a set point that prevents wheel slip is proposed. Having this estimation a conventional control algorithm maintains the system at the prescribed set point. If the external environment changes a new set point corresponding to the current condition is estimated. The estimation method is based on an adaptive observer design. The proposed control procedure does not rely on measured values of the slip ratio. The control algorithm is tested through simulation examples.
Friday September 16

8h30-10h00  Matlab session, Part I
10h00-10h30  Coffee Break
10h30-12h00  Matlab session, Part I
12h-14h      Lunch
14h-15h30    JM.Biannic
             LPV control methods in aerospace applications.
             In this talk, standard LPV control design techniques are first briefly reviewed and compared on simple examples. Then, the case of numerous scheduling parameters is investigated, as it often appears in aerospace applications. Strong limitations of standard approaches are highlighted for such cases and alternative strategies are proposed. A realistic application concludes the talk.

15h30-16h00  Coffee Break
16h30-18h00  O.Sename
             Underwater vehicles (LPV varying sampling control)
             This talk deals with the problem of varying sampling control of Linear Parameter Varying (LPV) systems. A discrete-time Linear Fractional Representation of a LPV system is used to design a gain-scheduled controller w.r.t some parameters representing the system non-linearities and the sampling interval. This method is compared with the usual polytopic method in the case of the pitch control of an autonomous Underwater Vehicle (AUV) which emphasizes the interest of such a methodology.