Ph.D. in Information Technology:

Manganini, Mura and Vignali Final Dissertations

DEIB Conference Room

January 19th, 2016

9.30 am

Ph.D. presentation and discussion:

Dr. Giorgio MANGANINI – XXVIII Cycle

"Optimal Control of Large Scale Stochastic Hybrid Systems with a Finite Control Space"

Supervisor: Prof. **Maria Prandini**

Abstract:

This thesis addresses optimal control design for discrete time stochastic hybrid systems characterized by a finite control space. The class of hybrid and possibly also stochastic systems has grown, motivated by the large variety of applications where continuous and discrete dynamics are strongly interacting and are affected by uncertainty. We develop two control strategies which share the same idea of effectively partitioning the state space into regions identified by the same optimal control action.

In the first part of the thesis we address the optimal control of discrete--time switched systems. The design of a switching law so as to minimize an infinite--horizon expected cost, while penalizing frequent switchings, has been addressed by means of a two stage algorithm: a classifier--like controller is trained with a set of optimal state-action pairs generated by mixed-integer quadratic programs.

In the second part of the thesis we turn to the optimal control of more general discrete--time stochastic hybrid systems. In particular we introduce a novel policy parametrization that adopts particles to describe the map from the state space to the action space, and tune its parameters by means of a model-free optimization algorithm.

Experiments on two benchmarks problems, i.e., the "Car on the Hill" example and a multi-room heating control problem, demonstrate the viability and scalability of the proposed approaches as the dimensionality of the state space grows. Eventually, theoretical analysis and approximation bounds are provided for the obtained control policies.

Second Ph.D. presentation and discussion:

Dr. Roberto MURA – XXVIII Cycle

"Robust Harmonic Control for Disturbance Rejection: Methods and Applications"

Supervisor: Prof. **Marco Lovera**

Abstract:

Harmonic control techniques aimed at reducing tonal disturbances have been extensively studied with particular attention to a representation of the system as a quasi-static model constructed in the frequency domain, the T-matrix model. The precise knowledge of its elements is necessary for a proper functioning of the overall control system, and classical employed controllers resorting to the linear quadratic theory have not be framed to deal with model and parametric uncertainties or nonlinearities, possible causes for degraded performance or instability of the closed-loop system.

In this work, a discrete-time LPV/H approach and a systematic methodology to the design of a Robust Harmonic Control algorithm is proposed, for both SISO and MIMO system representations, allowing to account for model and parametric uncertainty in the control design problem, and providing further benefits when dealing with the tuning problem. A set of validation experiments is finally proposed for the obtained control strategies, focusing on a classical Harmonic Control application like the Helicopter's rotor vibration problem.

Third Ph.D. presentation and discussion:

Dr. Riccardo Maria VIGNALI– XXVIII Cycle

"Automatic Verification and Input Design for Dynamical Systems: an Optimization-Based Approach to the Detection of Non-Influential Inputs"

Supervisor: Prof. **Maria Prandini**

Abstract:

As the complexity of control systems grows, the verification of their correct functioning assumes a more important role. In the testing phase, when the system is checked against possible misbehaviors, the verification task consists in computing the input sequence to be injected in the system so as to generate that undesired behavior. When such an inputs sequence is found, the cause of the malfunctioning can be understood and the design of the control system improved accordingly. Nonetheless, it may happen that the detected input sequence is too complicated to interpret, since, for example, it requires to

simultaneously set too many inputs. This prompts the need for novel verification methods, that provide "minimal" inputs sequences that satisfy a given specification (i.e., the misbehavior in the considered testing framework).

In this work we address this need and develop techniques for the maximization of the number of non-influential inputs, i.e., those inputs that can take an arbitrary value in their range without compromising the satisfaction of the specification. We address this problem for the class of discrete time linear systems and discrete time Piecewise Affine (PWA) systems, in the case of reachability and safety specifications. For linear systems we develop two different techniques. In the first technique we rely on an input parametrization that treats the inputs as set valued signals and formulate a linear optimization problem with the objective of maximizing the range on where each input can vary, with the constraint on the satisfaction of the specification. In the second technique, we rely on a parametrization that allows the influential inputs to depend on the non-influential ones and formulate a Mixed Integer Linear Programming (MILP) problem with the objective of maximizing the number of noninfluential inputs while enforcing the specification. As for the PWA case, we start by showing that an approach based on the extension of the first technique developed for the linear case leads to too conservative results. Prompted by the analysis of conservativeness, we reinterpret the problem from a geometrical perspective and formulate an exact approach to its solution, that, however, turns out to be intractable. On the base of this, we then construct an approximation of the exact problem that, despite being still conservative, leads to better results than the approach inspired by the linear case. As the approaches formulated for the PWA case can be computationally demanding, we also show, in the last part of this work, how to reduce their complexity via suitable techniques. In one of these techniques we show how to construct a reduced order PWA that preserves the input/output behavior of the original system by performing an extension of the classical observability analysis of linear systems.