Abstract of the thesis

ADAPTIVE MODEL PREDICTIVE CONTROL FOR UNCERTAIN LTI SYSTEMS WITH STATE AND INPUT CONSTRAINTS

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ABSTRACT

The design of control strategies for uncertain systems in safety critical environment is a practically relevant problem. Uncertainties in the system model may stem from various sources such as imprecise knowledge of system parameters, modelling imperfections, external disturbances, etc. Adaptive control addresses the problem of controlling uncertain system where the estimated controller/system parameters are adjusted online, based on measured input-output data, with guaranteed stability of the closed-loop system. Despite the fact that the theory of adaptive control is well established, only a few results address the problem of safe adaptive control design which can guarantee control performance under various safety constraints. To handle systems with hard constraints imposed on the states/outputs as well as inputs, model predictive control (MPC) has emerged as an efficient strategy. However, as the name suggests, MPC is a model dependent control strategy. For this reason, systems with parametric uncertainties in the model cannot be directly tackled by the conventional MPC strategy, owing to the difficulty in predicting the future states of the plant. The combined problem of controlling uncertain and constrained system can be handled by systematic combination of adaptive control with MPC. However, interlacing both aspects in control design is non-trivial and leads to challenging problems such as guaranteeing recursive feasibility of the MPC optimization routine in the presence of errors due to model mismatch between the uncertain system and the adaptive estimated system (utilized for predictions in MPC) and stability of the overall closed-loop system. The aforementioned prevailing issues motivate my current research objective, which is *to develop Adaptive MPC (AMPC) framework for constrained linear time-invariant (LTI) systems, which can guarantee safety through constraint satisfaction as well as stable closed-loop performance even in the presence of uncertainties in the parameters of the system model.* Detailed discussions regarding the issues of the conventional MPC as well as other strategies designed for handling constrained uncertain systems, are given in Chapter 1. This thesis has

three major contributions as briefly enumerated below, which also constitute the core essence of Chapters 2-4 respectively:

- Two decreasing horizon AMPC frameworks are proposed, which guarantee finite-time convergence of the states of the uncertain system to a suitably designed terminal set, while satisfying the imposed states and input constraints at all time instants. It is analytically proved that the proposed MPC optimization routine is recursively feasible if it is initially feasible, which in turn guarantees asymptotic stability of the overall closed-loop plant.

- A more general receding horizon framework for AMPC is proposed, which is an extension of the decreasing horizon AMPC framework. This design framework alleviates the problems associated with the decreasing horizon framework, such as reducing aggressive control action and utilizing the adaptive learning of estimated parameters for all instants of time. Recursive feasibility of the proposed MPC optimization routine is guaranteed if it is initially feasible, which in turn guarantees boundedness in the states of the uncertain plant at al time instants. It is further proved that the states of the overall closed-loop uncertain system are asymptotically converging to the origin.

- To further improve the closed-loop performance, multi-model adaptive identification strategy is systematically fused with MPC for controlling LTI systems with parametric uncertainty and hard constraints on states and inputs. The improvement in closed-loop performance is obtained through gradually reducing constraint tightening in the MPC optimization routine. The proposed AMPC strategy is also proved to be recursively feasible if it is initially feasible and the closed-loop states are guaranteed to be asymptotically converging to the origin.

All the control designs are validated through suitable simulation examples. At the end, concluding remarks and some future directions of this thesis are provided in Chapter 5.