Model Predictive Control Implementation for Modified Quadruple Tank System - DTU Orbit (21/07/2019)

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The implementation of a Model Predictive Controller (MPC) for a Modified Quadruple Tank (MQT) system is addressed in this thesis. The purpose of this study is to demonstrate the application of MPC to a multi-input-multi-output (MIMO) dynamical system that has complicated variables interactions. The basic understanding of the system and the controller is presented.

First, we investigate the behaviour of the dynamical system and determined the parameters and defined the variables that govern the MQT system, and then we derived all the formulations related to acquiring the mathematical model from the basic physical process. Then, the dynamic model of the system that has deterministic and stochastic components described as a linear discrete-time state space model derived is employed for the purpose of the next study. We specify the model in a form that is appropriate for computational operation and analysis of MPC by introducing a discrete impulse coefficient or known as Markov parameters.

Generally, the MPC consists of a state estimator and a constrained regulator, therefore for state estimation, a Kalman filter is incorporated. The computation of the coefficients is done off-line and the Discrete-time Algebraic Ricatti Equation (DARE) is used to obtain the stationary one-step ahead state error covariance matrix. The static Kalman filter is utilized to estimate the current state from the filtered part while the predictions part is used by the constrained regulator which is also known as an Optimal Control Problem (OCP) to predict the future output trajectory given an input trajectory. The objective of the OCP consists of tracking error term that penalizes deviations of the predicted outputs from the setpoint and a regularization term that penalizes the changes in the inputs which is the manipulated variables. The resulting OCP which is represented as a Quadratic Programming (QP) is solved and the performance of MPC is demonstrated through simulations using MATLAB is presented.

The study shows that the static Kalman filter is well executed and the estimation of the current states and the prediction of the future output trajectory are accomplished. Subsequently, the performance of the MPC is investigated. In this study, the MPC is implemented to unconstrained and constrained MPC. The unconstrained MPC is implemented to evaluate a first-hand straightforward performance of MPC and from the demonstration, disturbances are compensated and new setpoint was tracked, except an abrupt peak is visible in the flow of input variables indicates that it is infeasible for real application. The constrained MPC is formulated both for input and soft output constraints. When input constraint is introduced, the performance of MPC is exceptional although the transient response is slightly deprived, it is noticeable that the sharp peak in the flow of input variables is successfully suppressed, yielding a more relaxed flow. Whereas additional soft output constraint is included in the algorithm shows that the MPC operated as normal as the previous strategies without violating the input and output boundaries but the flow of the input variables is affected by a slight unsteady flow.

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