Theoretical Analysis of a Class of Multiple Model Interpolation Controllers

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Difficult process control occur when the process characteristics can change significantly in an unknown or unpredictable manner. The traditional control strategy is to use a conventional PI or PID controller that is conservatively tuned so that it maintains an adequate stability margin over the expected range of operating conditions. However, such conservative tuning sacrifices performance for all but the worst-case conditions. An alternative approach, adaptive control, has been extensively researched since the 1960's. Although general adaptive control strategies such as self-tuning control and model-reference adaptive control have a strong theoretical and have been successfully applied, experience has indicated that it is difficult to develop general purpose adaptive controllers that are sufficiently robust for industrial applications that are the responsibility of typical plant personnel, rather than adaptive control specialists.

In recent years, a promising alternative approach for adaptive control has been developed based on a set of model models and/or controllers. A variety of "multiple model" techniques have been reported in which an appropriate model (or controller) is selected for the current conditions. Typically, the model parameters, controller parameters, or controller output signals are based on an interpolation of the set of models or controllers.

This paper provides a theoretical analysis of the properties of a class of multiple model interpolation (MMI) techniques. Specific issues include model parameter convergence and closed-loop stability for realistic conditions that include set-point changes and both measured and unmeasured disturbances. The first part of the paper concerns model parameter interpolation based on a fixed model sets. Theoretical conditions for model parameter convergence and parameter estimation error are derived as a function of the number and spacing of the models. The analysis is then extended to the more general situation where the parameter estimation is based on a moving set of models that is centered about the current model. Finally, simulation results are included to investigate control system performance for a wide variety of changes in the static and dynamic behavior of the process.