

Development of a Nonlinear Model Predictive Control-Based Nonlinear Three-Mode Controller for a Nonlinear System

Suraj Suresh Kumar, Thirunavukkarasu Indiran,* George Vadakkekara Itty, Prajwal Shettigar J, and Tinu Valsa Paul

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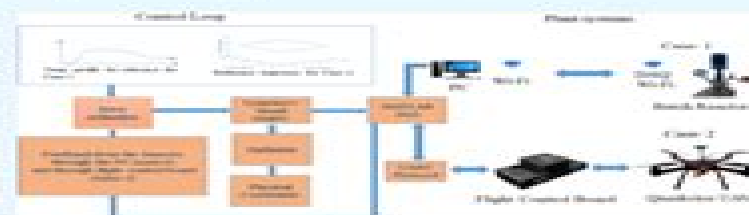
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ABSTRACT: This paper presents the novelty on a nonlinear proportional integral derivative (NPID) controller developed from the gain values obtained using the Lyapunov-based nonlinear model predictive controller (LyNMPC). The tuning parameters of the proposed controller are taken from the dynamics of the nonlinear system, and these parameters are dynamic with their value varying according to the error in the system. In this article, the authors have considered two highly nonlinear systems, namely, batch polymerization reactor and quadrotor unmanned aerial vehicle systems. The nonlinear mathematical modeling of the batch reactor as well as the quadrotor system considered from the past literature of authors. The acrylamide polymerization reaction under consideration is an exothermic reaction, thereby making the temperature profile tracking and control a challenging task. The primary aim of this article is to develop the NPID controller based on the LyNMPC algorithm and to validate the NPID on a batch reactor bench-scale plant and on an hardware-in-the-loop platform for the quadrotor hardware. A comparative study of trajectory tracking and control capabilities of LyNMPC on derived non-linear models of the batch reactor and quadrotor system is presented. The system mathematical models are obtained with the help of the first-principle energy balance equation for the batch reactor and with the nonlinear dynamics of the quadrotor which is derived based on Newton–Euler formulations. With LyNMPC, the stability of the nonlinear systems can be improved because the error sensitivity is considered in the cost function.



INTRODUCTION

The batch reactors are highly nonlinear and non-steady systems with the primary objective to maintain the reactor temperature with respect to the temperature profile. If the reactor temperature is not maintained with respect to optimal trajectory formed, the reactor may face thermal runaway issues,^{1–5} which in-turn is due to the sudden conversion of a polymer into a monomer. Hence the optimal control of coolant flow-rate should be used as a manipulated variable with constant heater supply in this experimental study. The highly nonlinear batch reactor stability needs to be ensured while tracking the trajectory to avoid the byproduct formation and thermal runaway. Similarly, unmanned aerial vehicles (UAVs) or drones have been under a rapidly growing field of research. The applications of UAVs have been growing day-by-day and can be categorized as scientific, commercial, or military applications. Micro-UAVs or micro-aerial vehicles (MAVs) are classified as miniature UAVs of different build configurations, which vary from the tiny insect sized aircrafts to the small quadrotors and the fixed wing aircrafts. The MAVs due to their smaller size range are more useful in the remote missions, show similarities with their

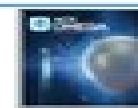
UAV counterparts in various characteristics but differ in terms of the magnitude of the aerodynamic forces experienced, and are more susceptible to external forces due to their smaller size and lower inertia. Hence, the problem of tracking and control of the MAVs is a much more challenging task to achieve.

Model predictive control (MPC) is a sophisticated control method which has various applications in the chemical and petroleum industries, where the physical hard constraints can be handled effectively. The MPC is a finite-boundary iterative optimization technique very useful in situ technique where the plant requirements vary with time. The MPC algorithm determines the control variables from the values obtained previously. Linear MPCs are the most common form of control used in the applications of MPC with the feedback

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