Abstract

Nguyen Duy Cuong, *"Advanced Controllers for Electromechanical Motion Systems"*, University of Twente, pp. xii+115, ISBN: 978-90-365-2654-8, 2008 (Supervised by van Amerongen, J. and de Vries, T.J.A.)

The aim of this research is to develop advanced controllers for electromechanical motion systems. In order to increase efficiency and reliability, these control systems are required to achieve high performance and robustness in the face of model uncertainty, measurement noise, and reproducible disturbances.
Proportional Integral Derivative (PID), Linear Quadratic Gaussian (LQG), Model Reference Adaptive Systems (MRAS) are typical conventional approaches where control designs involve compromises between conflicting goals. In general, for the PID control design, a compromise has to be made between performance and robust stability. In the LQG design the main issue is to trade-off attenuation of the process disturbances and the fluctuations created by measurement noise that is injected in the system due to the feedback. Direct MRAS offers a potential solution to reduce tracking errors when there are large changes in the process parameters. However, this control algorithm may fail to be robust to measurement noise. Indirect MRAS offers an effective solution to improve the control performance in the presence of parametric uncertainty and measurement noise. However, a small tracking error cannot always be obtained.
For motion control systems, Learning Feed-Forward Control (LFFC) may be used as a framework for solving the problems of reproducible disturbances. The solution is in the form of a two-degree-of-freedom controller, whose feedback and feed-forward paths independently provide the appropriate signals for disturbance rejection and model uncertainty. The use of LFFC can improve not only the disturbance rejection, but also the stability robustness of the controlled systems. Two main distinct methods, namely Neural Network (NN)-based LFFC and Model Reference Adaptive Systems (MRAS)-based LFFC, are investigated. Although both methods have been studied, little effort has been devoted to comparing or combining them. In this thesis, designs of NN-based LFFC and of MRAS-based LFFC have been developed for the high-performance robust motion control of a linear motor and a comparison of the two approaches has been evaluated. It is our first main contribution.
One of the main drawbacks of the NN-based LFFC is the requirement that the training motions are chosen carefully, such that all possibly relevant input combinations are covered. This requirement may be quite restrictive in practical applications. MRAS-based LFFC can be used to overcome such problem. By implementing both controllers on the Tripod setup, the performances of each method are compared. The experimental results show that both control algorithms reach almost the same tracking error after convergence and are superior to the PID controller. However, after convergence the MRAS-based LFFC is able to generate a much better feed-forward control and hence obtain about a 5 times smaller maxivi mum tracking error than the NN-based LFFC with an untrained reference motion. The reason for this is that MRAS-based LFFC can quickly generate appropriate actions for any coming input change. Moreover, compared to the NN-based LFFC, the MRAS-based LFFC is simpler to implement. The resulting control laws are simple and thus interesting for use in practical applications. Furthermore, an important difference is that the stability of the MRAS-based LFFC is analyzed by the Lyapunov theory. In other words, the stability properties of the MRAS-based LFFC are better understood.
We have shown that a combination of NN-based LFFC (to deal with nonlinearities, like cogging) and MRAS-based LFFC is superior to both systems alone. The combination performs better with respect to tracking errors and speed of learning and is simpler to realize. This is our second contribution. Both NNbased LFFC and MRAS-based LFFC can achieve good disturbance rejection, but the performance is limited by measurement noise.
In recent researches, variants of LQG have been used in combination with other algorithms to achieve better performance. Our third main contribution is the design of LQG combined with MRAS-based LFFC. This is a robust, highperformance control scheme that combines the advantages and overcomes the disadvantages of both types of techniques. In comparison to a PID controller, the LQG combined with MRAS-based LFFC has the following benefits: (1) it significantly reduces the tracking errors for any input reference signal; (2) it effectively improves the robustness with respect to changes in plant parameters and respect to measurement noise; (3) it can obtain faster transient response.