

The RRR-robot Feedback Control Design via Iterative Feedback Tuning

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Introduction

Control design can be model-based or data-based. A model-based design can deliver a high performance controller if the implemented model is an accurate description of the plant. Inaccuracies in the model limit the controller performance and may even lead to instability. It is sometimes time consuming and costly to model the plant accurately. Moreover, if the model is complex, the controller can be too complex for real time implementation. In data-based control design, the plant modelling step is omitted. Instead, the controller is derived using experimental data. In this work, a data-based control approach, called Iterative Feedback Tuning (IFT) [1], is investigated. This approach can be used to tune the parameters of a controller with a fixed structure.

Approach

Feedback design using the IFT approach begins with the definition of a performance criterion. Typically, the criterion simultaneously penalizes the difference between the desired and actual plant output (error) and the input to the plant. Furthermore, the designer selects a controller class of desired complexity with some parameters free to tune, *e.g.* a PID controller. The objective of IFT is to minimize the criterion by tuning the free controller parameters. The optimization is performed by an iterative method, which requires knowledge of the gradient of the criterion with respect to the controller tuning parameters. The key feature of IFT is the estimation of this gradient directly from the experimental data.

Experimental setup

The IFT algorithm is applied on a direct-drive robot. This robot has three revolute joints (RRR kinematics) and it exhibits strongly nonlinear dynamics. In previous work [2], a nonlinear model-based feed-forward compensation has already been designed. The dynamics that remain after compensation are decoupled and mostly linear. These remaining dynamics have already been identified and modelled. In this work, a feedback controller is designed for the remaining dynamics that correspond to the first robot joint, by using IFT. Only input-output data from the plant is used by the IFT algorithm, the model is merely used for simulation purposes.

Results

The IFT algorithm selected is adequate for the considered robot control problem. At each iteration step, two experiments are performed. The first experiment is performed under normal operating conditions. The second experiment is a special, dedicated experiment, where the error signal of the first experiment is used as reference signal. After appropriate processing of the process output of this special experiment, the gradient of the criterion with respect to the controller parameters is obtained. Subsequently, the controller parameters are updated. This algorithm is tested in simulations, based on a high-order linear model of the remaining dynamics. Next, the algorithm is implemented on the robot. In both cases, a minimum is found after several iterations. Finally, the controllers obtained during simulations and experiments are evaluated. It turns out that the third-order discrete-time controller, obtained with the IFT algorithm, results in increased performance compared to the initial, weakly tuned PD controller, see figure 1. The resulting controllers during simulations and experiments are not identical. Differences are explained by unmodelled dynamics.

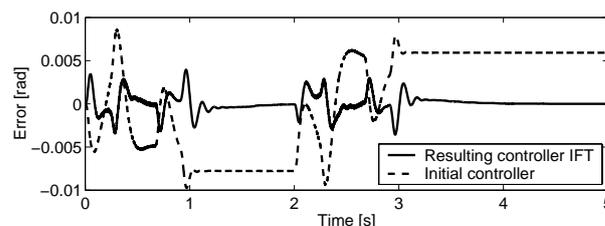


Figure 1: Tracking error during experiments

References

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- [2] D. Kostić, B. de Jager, M. Steinbuch, "Experimentally Supported Control Design for a Direct Drive Robot," Proc. of the 2002 IEEE Int. Conf. on Control Applications, Vol. 1, pp. 186-191, 2002.