A reference free iterative learning strategy

Bruno Depraetere\textsuperscript{1}, Gregory Pinte\textsuperscript{2}, Jan Swevers\textsuperscript{1}

\textsuperscript{1} Department of Mechanical Engineering, Division PMA, Katholieke Universiteit Leuven
\textsuperscript{2} Flanders Mechatronics Technology Centre
Celestijnenlaan 300B\textsuperscript{1} / 300D\textsuperscript{2}, 3001 Heverlee, Belgium
Email: bruno.depraetere@mech.kuleuven.be

1 Introduction

Many mechatronic applications are characterized by complex, non-linear behavior. An extensive effort is then required to derive accurate models for the purpose of control. When the behavior varies over time, this also has to be taken into account. To address these issues, learning can be introduced for similar or repetitive operations. However, typical learning techniques such as iterative learning control (ILC) focus on improving tracking control, and are of little use when no appropriate reference trajectories are available.

This work proposes to formulate the performance specifications directly as a numerical optimization problem. Before each iteration, this problem is solved using a piecewise-linear model and assumed numerical values for all constraints. The optimized control signal is then applied to the system, and the measured response is used to adapt the models and constraints before the next control signal is calculated. This results in a two level control structure with the optimization procedure on the low level, being fed models and constraints by the high level.

2 Wet clutches

An example of such a mechatronic application is a wet clutch, typically used in automatic transmissions of off-highway vehicles to transmit power from the motor to the load. The goal is to engage the load as fast as possible, yet without introducing oscillations of the drivetrain. Good models are hard to derive as the dynamics are non-linear, with a sudden change of dynamics once the torque transfer starts. In addition, the environmental conditions vary between several engagements, as do the load and the amount of wear. A last difficulty is a lack of sensors, as suitable, fixed reference trajectories are unavailable for the measured variables. For industrial clutches, these problems are avoided using experimental calibrations that are repeated regularly to compensate for system variation, requiring the machine to be taken out of production.

To avoid these (re)calibrations, the proposed learning algorithm is applied. On the low level, the time required to engage the clutch is minimized by solving a time-optimal control problem. The high-level learning controller is used to recursively identify several linearized models, such that a piecewise linear model can be used for the optimization. It also contains learning algorithms to automatically select the values of several constraints based on the observed engagement quality, such as the transitional states of the piecewise model.

3 Experimental validation

The developed control scheme has been validated on an experimental test setup. To analyze the performance, Fig. 1 shows the normalized slip (difference in rotation speed between input and output shaft) and torque during the 1st, 3rd and 10th engagement of the convergence process at fixed conditions. The slip profile, while initially choppy, becomes very smooth, with low values of the jerk. Similarly, the transferred torque initially shows peaks, which are then removed by the learning process. Eventually fast and comfortable engagements are thus obtained. To analyze the robustness, various operating conditions have also been tested, and convergence towards good engagement quality was obtained for all cases.

Acknowledgement This work has been carried out within the framework of projects IWT-SBO 80032 (LeCoPro) of the Institute for the Promotion of Innovation through Science and Technology in Flanders (IWT-Vlaanderen) and G.0422.08 of the Research Foundation - Flanders (FWO - Vlaanderen). This work also benefits from K.U.Leuven-BOF EF/05/006 Center-of-Excellence Optimization in Engineering and from the Belgian Programme on Interuniversity Attraction Poles, initiated by the Belgian Federal Science Policy Office.