Iterative learning control with an identified time-varying robot model

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1 Introduction

Demanding applications like laser welding require the tip of an industrial robot to move with an accuracy of ± 0.1 mm at speeds beyond 100 mm/s. This accuracy is not feasible using standard industrial controllers. Since industrial robots have a good repeatability, the use of Iterative Learning Control (ILC) is investigated.

2 Method

Previously a model-based ILC algorithm was developed for linear time-varying systems and it was applied successfully to reduce the low-frequent tracking error of an industrial robot [1]. Compensation for high-frequency tracking errors requires adequate modelling of the high-frequency robot dynamics, which is affected by the elasticity of the mechanism.

The configuration dependent robot dynamics is modelled as a linear time-varying (LTV) system by interpolating several autoregressive models with external inputs (ARX) along the trajectory. The input-output relation of this model is

$$y(t) = \sum_{i=1}^{N_i} p_i(t) \left(\sum_{\tau=N_k}^{N_b} b_{i,\tau} u(t-\tau) - \sum_{\tau=1}^{N_a} a_{i,\tau} y(t-\tau) \right) + v(t),$$

where $u(t)$ is the input, $y(t)$ is the output and $v(t)$ is noise. Parameters $p_i(t)$ are predefined parameters that interpolate the parameters $a_{i,\tau}, b_{i,\tau}$ of the N_i ARX-models. The parameters $a_{i,\tau}, b_{i,\tau}$ can be estimated using linear regression.

3 Results

The performance of ILC with the LTV-ARX model is tested for the setup shown in figure 1. The robot tip moves with a speed of 200 mm/s from the initial position in the picture towards the robot's base. Perpendicular to this main motion

Figure 1: *Stäubli RX90 robot at the start of the trajectory*

the robot tracks the saw-tooth profile of a metal strip. An optical sensor measures the position of the metal strip relative to the robot tip. The LTV-ARX model structure is used to describe the relation between the commanded motion and the measured motion perpendicular to the main motion. The model parameters are identified and two local frequency responses are shown in figure 2. The figure clearly shows the increase of the resonance frequencies as the robot retracts. Figure 3 shows the achieved tracking error reduction when the model is used for ILC.

4 Conclusions

The tracking accuracy of an industrial robot can be improved in a wide frequency band using model-based ILC and an ARX-LTV model. Model structure selection and estimation of the model accuracy are subject of ongoing research.

References

[1] W.B.J Hakvoort et al., 2006. Iterative Learning Control for Linear Time-Varying systems with application to an industrial robot. In: Book of Abstracts 25th Benelux Meeting on Systems and Control. Page 32.

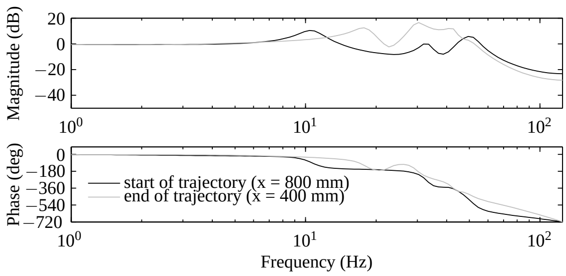

Figure 2: *Local frequency responses of the robot model*

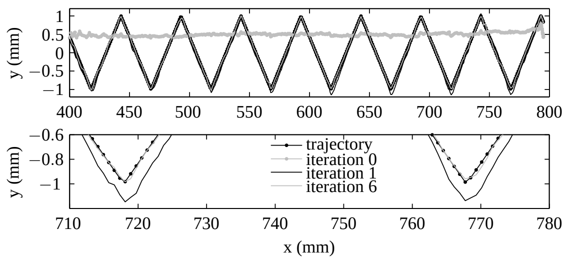

Figure 3: *Trajectory and motion of the robot tip*