Parameter Optimisation Techniques for Robot Identification and Realistic Dynamic Simulation

R.R. Waiboer[1], R.G.K.M. Aarts and J.B. Jonker

[1]Netherlands Institute for Metals Research
Laboratory of Mechanical Automation, University of Twente.
Institute of Mechanics, Processes and Control - Twente.
P.O. Box 217, 7500 AE Enschede.
phone +31-(0)53-4895442, email r.r.waiboer@utwente.nl

Robotised laser welding is an application, which requires high tracking precision at high speed motions. For prediction of the weldability of a seam, a closed-loop dynamic simulation of the robot is essential. In order to accurately predict the path tracking errors of the robot along a laser welding seam, realistic dynamic robot models with accurate model parameters are crucial. An accurate model of an industrial robot must therefore include all significant dynamic properties, such as inertia and joint friction. Furthermore, the robot controller should be included in the model as well.

For the modelling of the manipulator arm, a non-linear finite element formulation [2] has been applied, in which links and joints are modelled by beam and hinge elements. The identification of the inertia properties is based on an inverse dynamic identification technique. For this purpose, the dynamic model is written in a so-called parameter linear form:

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$$\underline{\tau} = \Phi(\underline{\ddot{q}}, \underline{\dot{q}}, \underline{q})\underline{p} \tag{1}$$

where the joint torques $\underline{\tau}$ are expressed as a product of the regression matrix $\Phi(\underline{\ddot{q}}, \underline{\dot{q}}, \underline{q})$ and the inertia parameter vector $\underline{p}$. The regression matrix is a function of the joint position $\underline{q}$, velocity $\underline{\dot{q}}$ and acceleration $\underline{\ddot{q}}$. In an inertia identification experiment, the robot is moved along an excitation trajectory $\underline{q}(t)$, while the joint torques are recorded. Using a linear least squares optimisation, the unknown inertia parameters are found. For an optimal identifiability of the parameters, the trajectory is optimised for persistent excitation, while motion constraints are obeyed.

To prevent backlash, the bearings in the joints are highly prestressed. Unfortunately, this results in high joint friction torques, which are quite dominantly present in the total joint torque. Therefore, friction must be taken into account in the inertia identification in order to achieve accurate values for the inertias. The friction models can be identified independently from the inertias using dedicated experiments. For the modelling of the joint friction, the LuGre [1] model is used. It is adapted for non-linear viscous friction at high velocities.

The controllers of industrial robots are generally very closed. In order to model the controller, it has been reverse engineered by means of standard system identification tools. The controller model has been included in the complete closed-loop robot model within MATLAB/SIMULINK. In the presentation, the modelling, identification and simulation of an industrial robot (Stäubli RX90) will be demonstrated by comparing simulation results with measurements of a motion experiment.

References

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