Modeling and Control of Flexible Link Manipulator (A220.401)

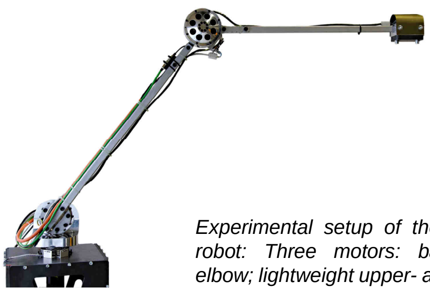
AUSTRIAN CENTER OF COMPETENCE IN MECHATRONICS

Area 2 – Mechanics and Model-based Control

Framework

The pressure of time for the automated production in industry increases more and more. A solution is the usage of light-weight structures leading to fast movements and energy saving manipulators. However, these structures tend to vibrate when accelerating to high velocities which is a crucial drawback. Respective control schemes in combination with an appropriate trajectory generation offers the ability to minimize the vibrations.

As experimental setup, an articulated robot with two flexible links and three flexible joints is under consideration.



Experimental setup of the elastic articulated robot: Three motors: base, shoulder and elbow; lightweight upper- and forearm

Modeling

A detailed dynamical model is the basis for a model based control design. Due to the complexity of the system an efficient method for modeling repeating assemblies (motor, Harmonic Drive Gear, flexible link, tipmass), namely the Projection Equation in subsystem representation

$$\sum_{n=1}^{N}\left(\frac{\partial \dot{\mathbf{y}}_n}{\partial \dot{\mathbf{q}}}\right)^T\left[\mathbf{M}_n\ddot{\mathbf{y}}_n+\mathbf{G}_n\dot{\mathbf{y}}_n-\mathbf{Q}_n^e\right]=0$$

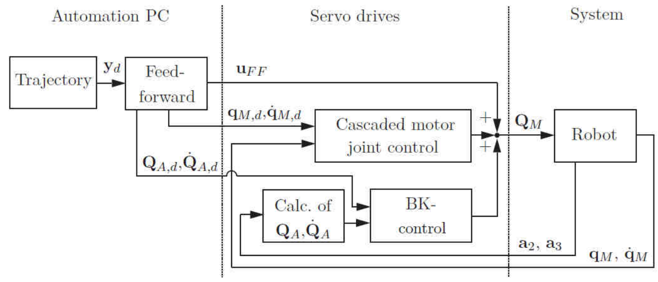
is used. A Ritz approximation for the distributed parameters is introduced, e.g. $w(x,\ t)\ =\ \mathbf{w}(x)^T\ \mathbf{q}_{Rw}(t)$, ..., leading to ordinary differential equations.

This very detailed simulation model is not advisable for the control design. Therefore simplified mass-spring-damper models are extracted for this task.

Control

A two degree of freedom control scheme is selected for solving the tracking problem on the flexible link manipulator. Such an approach allows to design the feedforward part independently form the feedback part.

In this project the feedforward control is based on the flatness approach, while the feedback control of the remaining tracking error dynamics is designed with passivity based concepts, like backstepping control and the interconnection and damping assignment – passivity based control (IDA-PBC) approach for instance.

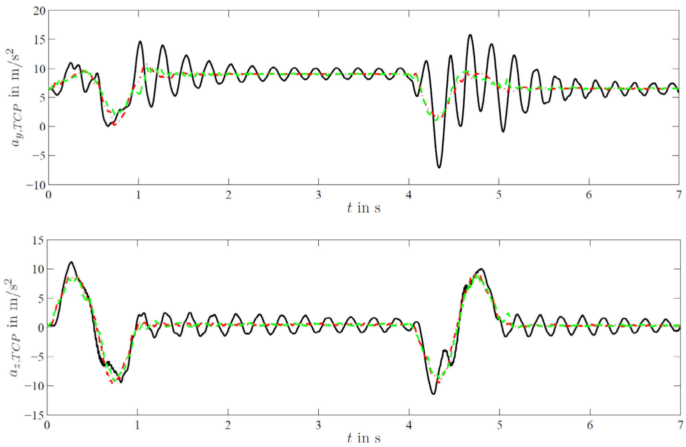


Implementation of the backstepping control (BK) using an observer calculating the arm torques $\mathbf{Q}_A$ for the feedback loop.

Since the suggested concepts assume a complete set of system states, an observer is applied, using the information of the angular rate- and acceleration sensors.

Results

Comparing the suggested concepts and a commonly used PD-motor-joint-control along a fast straight line in space shows a great improvement in terms of vibration suppression and tool center point accuracy.



Comparison of tool center point accelerations: black: PD-motor joint-control; red: backstepping control; green: IDA-PBC

References

(1) P. Staufer, H. Gattringer, W. Höbarth, H. Bremer. Passivity Based Backstepping Control of an Elastic Robot. ROMANSY 18: Robot Design, Dynamics and Control, CISM Courses and Lectures, Vol. 524, Springer, 2010

(2) P. Staufer, H. Gattringer. Passivity Based Tracking Control of a Flexible Link Robot. ACCM Workshop on Multibody System Dynamics, Robotics and Control, 2012 (accepted)

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