Motivation
- flexible multibody dynamics modeling
- nonlinear observer design for a very flexible manipulator to estimate full states and the end-effector position
- nonlinear actuator control of an underactuated robot based on the drivers position and velocity
- experiments with a nonlinear observer on the lambda robot

System Modeling
- equations of motion of the multibody system
  \[ M(q) \ddot{q} + C(q, \dot{q}) + \lambda = B(q) \cdot u + g(q) \]
- \( \lambda \): reaction forces due to the constraints
- \( C(q, \dot{q}) \): loop closing constraints

Nonlinear Observer
There is no direct feedback of the end-effector position and all states of the nonlinear system. In order to estimate them, a nonlinear observer is designed. Nonlinear dynamic of the lambda robot

\[ x = g(x) + H(x) \cdot u = f(x), \]
\[ y = C \cdot x \]

input controller \( u = Kx \), where \( K \) is a constant gain matrix

estimation of the lambda system states

\[ \dot{x} = f(x) + L(y - x), \]
\[ \dot{\hat{x}} = C \cdot \dot{x} \]

estimation error

\[ e = x - \hat{x} \]

this error converges asymptotically to zero

Experimental Setup
In order to validate the end-effector position, a camera is used to track the end-effector position. The image processing of the recorded image for the end-effector positions is accomplished offline.

Experimental Results
To estimate the end-effector position and the states of the lambda robot, the mover positions and velocities and the deformation of the flexible long link are used.

The experimental estimation results for the nonlinear trajectory show the designed observer estimates of the states and the end-effector positions with high accuracy.

Conclusions
- high speed trajectory tracking using a combination of the feed-forward and feedback controller
- using the deformation of the long link position and velocity of the movers, the states and end-effector position are estimated
- a nonlinear dynamic controller shall be designed based on the observer estimation for the underactuated system

References