UNIVERSITÄT ZU LÜBECK
INSTITUTE FOR ROBOTICS
AND COGNITIVE SYSTEMS

Humanoid Robotics
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# Exercise sheet 1 - Kinematics

Please prepare the following exercises for the upcoming tutorial.

## Task 1: Cart-Pole - Equation of Motion

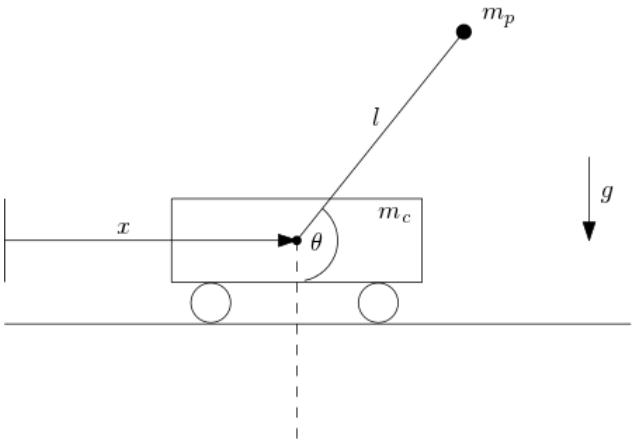


**Figure 1** Cart-Pole

The cart-pole, which is shown in Figure 1, shall be analyzed. Therefore the equations of motion have to be determined. We recommend to use the Lagrange equation. Further, the generated system of equations shall be inserted into Matlab as a simulation model. A simulation of the cart-pole for $t \in [0s, 10s]$ using an ODE solver, e. g. ODE45, shall be performed given the following specifications,

$$\begin{aligned} l &= 1.0\,\mathrm{m} \\ m_c &= 1.0\,\mathrm{kg} \\ m_p &= 1.0\,\mathrm{kg} \\ g &= 9.81\,\mathrm{m/s^2} \\ x(t=0) &= 0.0\,\mathrm{m} \\ \dot{x}(t=0) &= 0.0\,\mathrm{m\,s^{-1}} \\ \theta(t=0) &= 0.5\pi\,\mathrm{rad} \\ \dot{\theta}(t=0) &= 0.0\,\mathrm{rad/s}. \end{aligned} \tag{1}$$

## Task 2: Cart-Pole - Inverse Kinematic

The end effector position of the cart-pole from Figure 1 shall be steered to $[1.0\,\mathrm{m}, 0.5l]^\top$. Use inverse kinematics in order to determine the required angle $\theta$ and position $x$ of the cart-pole. Please use three different approaches (Geometric, Newotn and Gradient based) in order to calculate the desired angle $\theta$ and position $x$.

## Graded Assignment 01: Inverse Kinematics

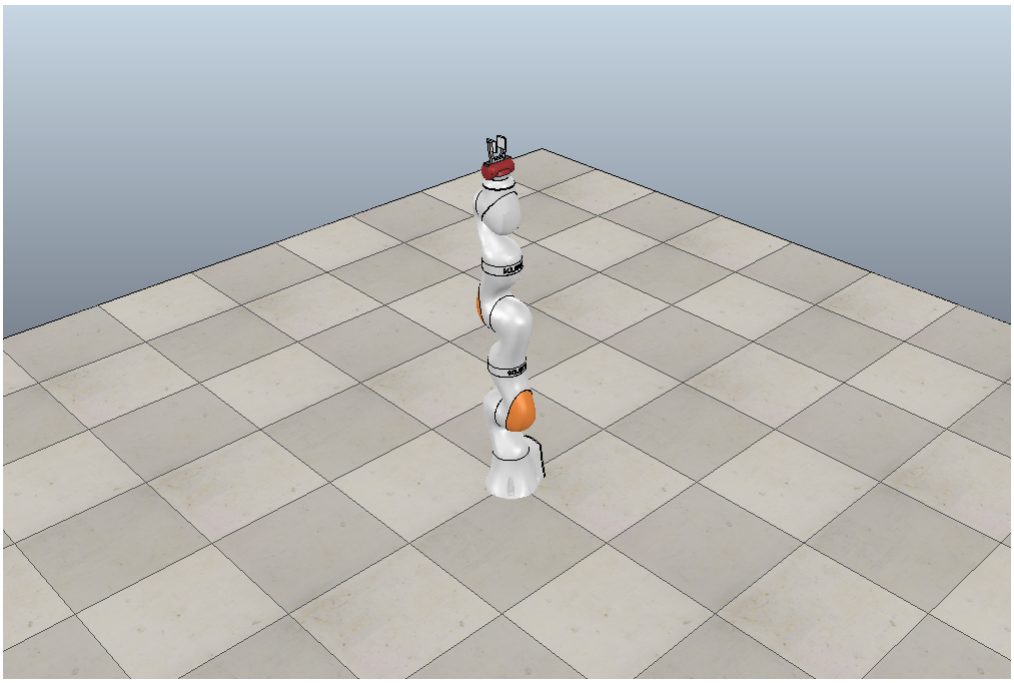

**Figure 2** Robot Scenario

In this assignment you will use inverse kinematics in order to steer a gripper mounted on a KUKA robot arm to three different positions. The scenario is shown in Figure 2 and can be downloaded here. You will also find a Matlab file which generates for you a Matlab object in which the dimensions of the KUKA robot are stored. The desired positions of the gripper are

- $[0.7, 0.2, 0.4]^\top$
- $[0.0, -0.5, 0.5]^\top$
- $[0.5, 0.5, 0.5]^\top$

In Figure 3 an example of the gripper at the first position is shown.

In order to pass the assignment you have to write a Matlab code which steers the KUKA robot to the desired positions using both the Newton and the Gradient inverse kinematic method for calculation of the desired angles $q_i$. The Matlab code has to be executable with the running V-Rep Environment. In addition, 2-3 pages as a PDF document have to be submitted. In this document the principles you used as well as your results shall be presented. A Latex draft and an example can be found here

The submission deadline for this assignment is May 22, 2018, 10am. Please send your submission as a Zip data named RO5300_TeamNumber to Nils.Rottmann@rob.uni-luebeck.de with the subject RO5300_TeamNumber. Other submissions will not be considered.
If you have any problems with the assignment feel free to get in touch. You will find me in Building 64, Room 85.

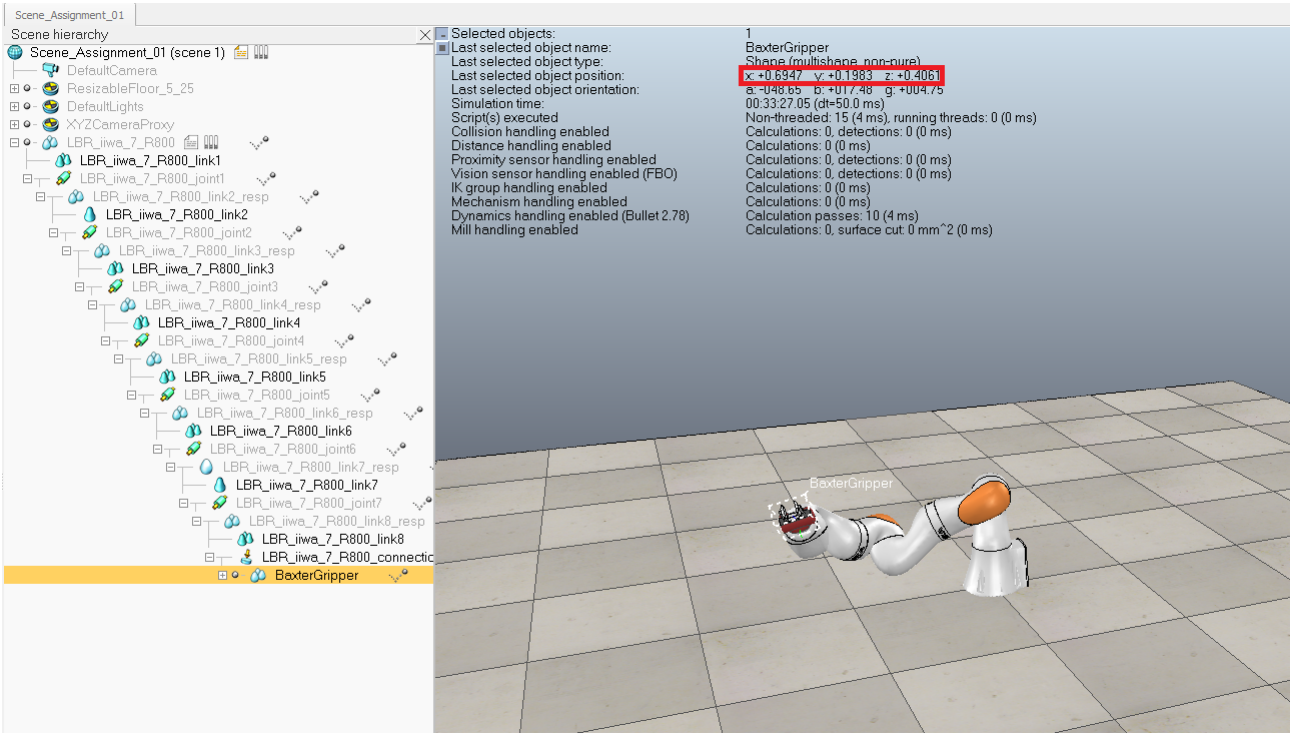


**Figure 3** Example Gripper Position