System sketch
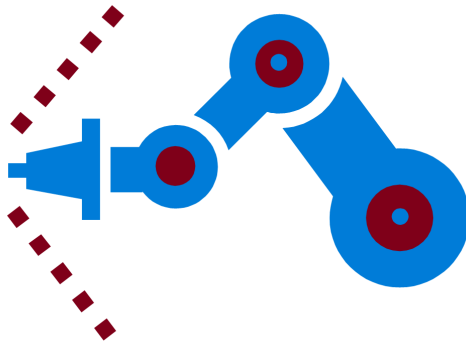# Modeling and control of an industrial robot

Version 1.0

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Date: September 29, 2011

Status

Reviewed	Alexander Pettersson	2011-09-22
Approved	Patrik Axelsson	2011-09-22

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Document History

Version	Date	Changes made	Sign	Reviewer
0.1	2011-09-15	First draft.	JK	André Carvalho Bittencourt
0.2	2011-09-20	First revision.	JK	Patrik Axelsson
0.3	2011-09-21	Second revision.	JK	Patrik Axelsson
1.0	2011-09-22	First version.	JK	Patrik Axelsson

Course name:	Control Project Laboratory	E-mail:	toban607@student.liu.se
Project group:	Industrial robot	Document responsible:	Tobias Andersson, Jonas Källman
Course code:	TSRT10	Author's E-mail:	toban607@student.liu.se
Project:	Industrial robot	Document name:	System sketch.pdf

Contents

1 Introduction

A control system for an industrial robot will be created from scratch, including the modeling of the robot. The user interface will send move orders to the robot. The model will contain the kinematics and the dynamics of the system. The model will be used to plan the trajectory and then use the controller to move the robot.

2 Overview of the system

After an order to move has been sent from the user interface, the trajectory planner will plan the movements using the model and send the trajectory as a reference signal to the controller, which is using the same model.
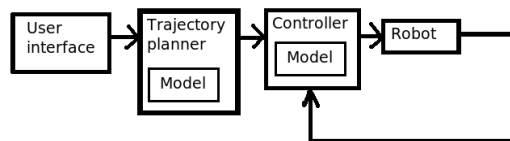

Figure 1: Block representation of the system.

2.1 Robot description

The robot was built by mechanical engineering students. The robot has six joints, but the control system will only be built for the first three joints. That means; it is possible to reach all positions within the robot's reach but it is not possible to change the orientation of the tool. A computer is needed to control the robot. The communication between the robot and the computer is done with Labview.
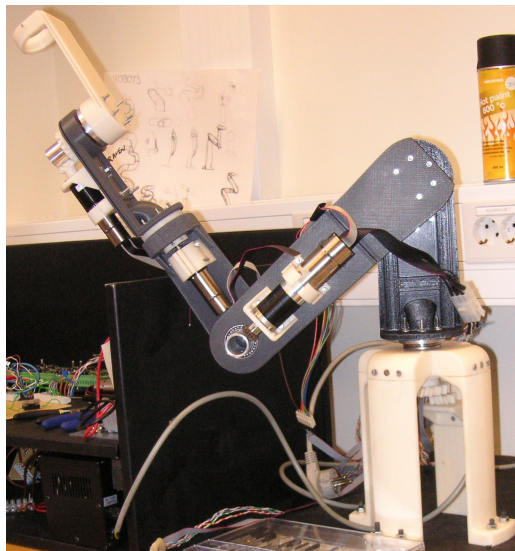

Figure 2: Picture of the robot.

3   User interface

The user interface will send orders to the robot and it will have both a manual and an automatic mode. The manual mode will be used to jog the different joints of the robot one joint at the time. The automatic mode will be used when the robot should move to a specific point either by moving the joints to the correct angle or moving the tool along a straight line. The user interface will be implemented in Matlab which communicates with the robot through Labview.

4   Model

The model consists of two parts, the kinematics and the dynamics.

The forward kinematics is a model that calculates the tool position from the arm angles

$$X = \psi(q), \tag{1}$$

where q are the arm angles and X the tool coordinates. The inverse kinematics is a model that calculates the arm angles from the tool position,

$$q = \psi^{-1}(X). \tag{2}$$

The flexible dynamic model is on the form

$$M(q)\ddot{q} + C(q, \dot{q}) + G(q) + D(\dot{q}) + K(q) + F(\dot{q}) = \tau, \tag{3}$$

where q are the arm and the motor angles, M is the joint-space inertia matrix, C includes Coriolis and centrifugal forces, G includes external forces (gravity), D includes damping, K includes spring forces and F includes friction. τ is the applied torque [1]. System identification will be used for unknown parameters in (3). The unknown parameters are the parameters for the damping, spring and friction.

5   Trajectory planner

The trajectory planner will be used when automatic mode is enabled, i.e. when the robot is moving from position A to position B either along a straight line or by moving the joints and ignoring the path of the tool. It will calculate all the angles as a function of time and send it as a reference signal to the controller. With help of an existing toolbox designed during a master thesis at the division of automatic control, the joint angles can be calculated for different points on the straight line between A and B. Based on the output from this toolbox and the desired speed, the angles as function of time can be calculated. The trajectory planner will also make sure that the robot does not collide with itself or an object.

6   Controllers

The joint controller will be used to control the movement of the joints. The controller will be implemented in Matlab along with a model of the system so that testing can be done before the controller is used on the robot. It receives a reference signal from the trajectory planner in the form of an angle. The controller output will be the desired torque for the

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Project:	Industrial robot	Document name:	System sketch.pdf

motors, which will be transformed in to a current or voltage which will be applied on the motors. The dynamics model will be used to feed forward the reference angles and a feedback of the angles is done from the robot, see figure 3.
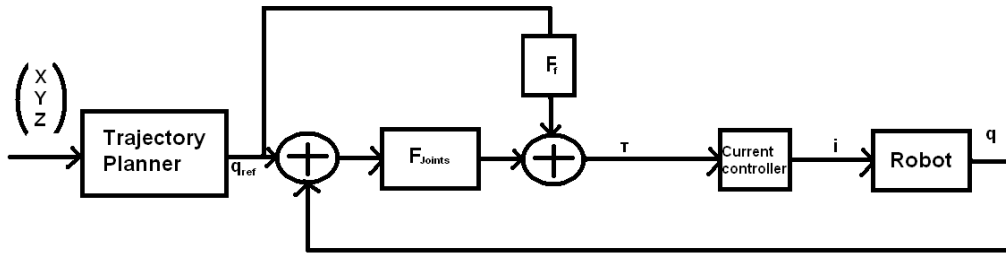

Figure 3: Block representation of the control system.

References

[1] Craig, John J., *Introduction to robotics: Mechanics and control.* Pearson Education, 3rd Edition, 2005.