Test plan
Modeling and control of an industrial robot

Version 1.0

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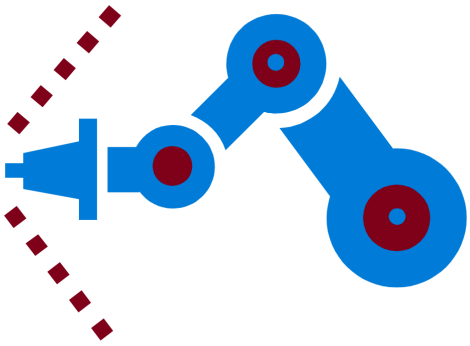

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Document History

Version	Date	Changes made	Sign	Reviewer
0.1	2011-10-03	First draft.	GA	André Carvalho Bittencourt
0.2	2011-10-07	First revision.	GA, TA	Patrik Axelsson
0.3	2011-10-10	Second revision.	AP	Patrik Axelsson
1.0	2011-10-11	First version.	AP	Patrik Axelsson

Contents

1 Introduction

This project is a cooperation between a student group at Linköping University and ABB Robotics, with the goal to control an industrial robot which was build by Mechanical Engineering students 2010. This document is a description of the tests that are to be performed in order to verify that all the requirements in the requirement specification [1] are met. It is important to know how to verify all requirements to be able to show the orderer that all requirements indeed are met.

A picture of the robot and the control electronics can be seen in figure 1.

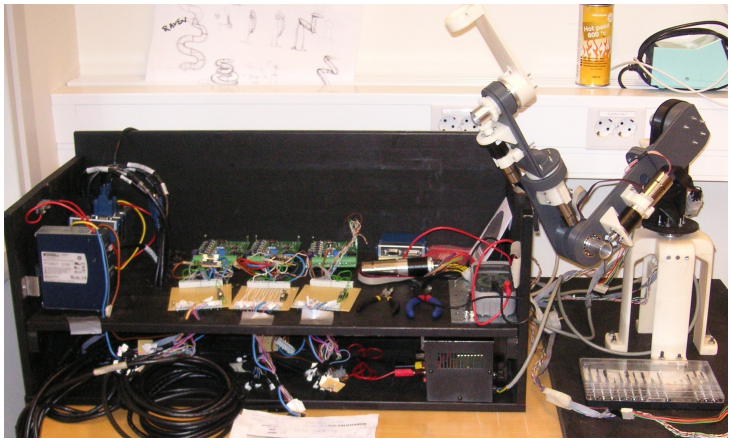

Figure 1: A picture of the robot and the control electronics.

1.1 Parties

The customers of the project are Mikael Norrlöf at ABB Robotics and Johan Sjöberg at ABB Corporate Research. An orderer, Patrik Axelsson, and an advisor, Andre Carvalho Bittencourt, are also connected to the project.

1.2 Purpose and goal

The purpose with this document is to describe the tests that are to be performed in order to validate the models and to evaluate the control system designed in this project.

1.3 Background information

This project is a part of the CDIO-course TSRT10 at Linköping University and is a collaboration with ABB Robotics. The group consists of 8 students at the Mechanical Engineering program and Applied Physics and Electrical Engineering program.

2 Guidelines

A number of guidelines are developed, which will help the group to have the right tools, knowledge and material when the tests are performed. The purpose of the tests is to

verify the requirements. This chapter describes how the tests shall be performed. This document describes tests to investigate requirements of all priority levels.

2.1 Definition of a test session

A test session is an activity where at least 2 persons perform a test according to the test plan. The tests can either fulfill the requirements or not. To fulfill a requirement all tests concerning this specific requirement have to be passed.

2.2 Participants

At least 2 persons are responsible for the execution, verification and recording of a test. One of them act as a secretary and is responsible to keep records according to the test protocol in Section 5. A test manager also attends at the test to supervise and ensure that the tests are correctly executed. The test manager approves or rejects the test and is selected individually for each test.

2.3 Test criteria

The test criteria determine whether the test passes or fails the requirement. If a requirement is not met, the test has to be preformed again after changing what is believed wrong. A requirement is met when all tests concerning the specific requirement is passed a minimum 5 times in a row during a test, see table 2 for more information.

2.4 Interruption of a test

If the test manager or secretary has to leave the test before it is completed, a new test manager or secretary has to be elected. If the total number of participants is below the minimum level of two persons, the test has to be postponed.

2.5 Test report

During each test, a test report must be written, a template is available in Section 5. The test report declares which group members who were present, who was the test manager and who was the test secretary. It is also stated how the test was executed and whether the requirements were met. After the test, the test manager of the project will review the report in a maximum of 2 working days.

3 Test sessions

This section describes the different test sessions that are to be executed during the project.

Test 1: Forward kinematic model

Objectives:	Validating the forward kinematic model
Achievements:	Accurate forward kinematic model
Tasks involved:	Definition of at set of at least 12 joint coordinate angles for the validation Simulate the robot kinematics in those points Measurement of achieved angles on the actual robot, by keeping the robot with hands Comparing the model and measurements
Test criteria:	An accuracy of $\pm$ 2 cm should be achieved at least 12 times in a row
Resources needed:	Robot Computer Length and angle measurement tools
Requirements tested:	9, 10, 17, 18
Preliminary schedule:	2011-10-24 to 2011-10-28
Preliminary responsible:	AG, VI

Test 2: Inverse kinematic model

Objectives:	Validating the inverse kinematic model
Achievements:	Accurate inverse kinematic model
Tasks involved:	Definition of at set of at least 12 joint coordinate angles for the validation Calculating the position with the forward kinematic in those points Calculating the angles with the position gained from the forward kinematics using the inverse model Comparing the validation joint angles with the calculated
Test criteria:	An accuracy of $\pm$ 2 $^\circ$ should be achieved at least 12 times in a row
Resources needed:	Computer
Requirements tested:	9, 10, 17, 18
Preliminary schedule:	2011-10-24 to 2011-10-28
Preliminary responsible:	AG, VI

Test 3: Manual control with Labview

Objectives:	Controlling the motors in Labview
Achievements:	A manual operation mode in Labview
Tasks involved:	Define a set of 15 angles Using Labview to make the robot move to the correct angles Comparison of the angles
Test criteria:	An accuracy of $\pm 2^\circ$ should be achieved at least 15 times in a row
Resources needed:	Robot Computer Angle measurement equipment
Requirements tested:	22
Preliminary schedule:	2011-10-24 to 2011-10-28
Preliminary responsible:	JK, TA, AP

Test 4: Manual control of the robot with the interface

Objectives:	Controlling the robot with the interface
Achievements:	The robot moves to a set of angles defined in the user interface
Tasks involved:	Define a set of 15 angles Using the interface to make the robot move to the correct angles Comparison of the angles
Test criteria:	An accuracy of $\pm 2^\circ$ should be achieved at least 15 times in a row
Resources needed:	Robot Computer Angle measurement equipment
Requirements tested:	23
Preliminary schedule:	2011-10-24 to 2011-10-28
Preliminary responsible:	JK, TA, AP

Test 5: Dynamic model

Objectives:	Validating the dynamic model
Achievements:	Accurate dynamic model Accurate model parameters
Tasks involved:	Definition of at set of at least 12 joint coordinate angles, angular velocity and angular acceleration for the validation Calculating the torque for the input Estimating the angular velocity and angular acceleration Comparing the validation joint angular velocity and angular acceleration with the calculated
Test criteria:	An accuracy of ± 5% should be achieved at least 12 times in a row
Resources needed:	Robot Computer Kinematic model Estimated unknown parameters Equipment for measuring the angles over time
Requirements tested:	11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21
Preliminary schedule:	2011-10-15 to 2011-10-31
Preliminary responsible:	KK, GA, AS

Test 6: Current controller

Objectives:	Validating the current controller
Achievements:	Accurate torque to current conversion Accurate torque to current control loop
Tasks involved:	Definition of constant torque over a period of 10 seconds Simulation of the defined torque Measurements of the motor currents on the robot with the same torque as in the simulation
Test criteria:	An accuracy of ± 10% should be achieved at least 8 times in a row
Resources needed:	Robot Computer Kinematic model Dynamic model Equipment for measuring the current
Requirements tested:	24
Preliminary schedule:	2011-10-15 to 2011-10-31
Preliminary responsible:	KK, GA, AS

Test 7: Simulating the robots control system in Matlab/Simulink

Objectives:	Simulating the robots movement in Matlab/Simulink
Achievements:	Working torque controller Working control system
Tasks involved:	Define a set of 15 different reference signals of length 10 seconds Simulate the control system with the given reference signals Compare the simulated angles against the reference signal
Test criteria:	Stationary error less then ±10% (priority 1) or ±5% (priority 2) should be achieved at least 15 times in a row
Resources needed:	Computer
Requirements tested:	25, 27, 28, 29, 30, 36, 37
Preliminary schedule:	2011-10-15 to 2011-10-31
Preliminary responsible:	AG, VI, GA

Test 8: Simulation of the trajectory planner

Objectives:	Simulating the robots movement in a straight line in Matlab/Simulink (priority 1) Simulating the robots movement in a non-linear trajectory in Matlab/Simulink (priority 2)
Achievements:	Working trajectory planner
Tasks involved:	Define a set of 10 different target positions and 10 different target angles Simulate the trajectory by using the trajectory planner Calculate the tools position over time with the forward kinematics model Compare the calculated tool position against the line between the current position and the target position
Test criteria:	Deviation from the trajectory should be less then ± 10%
Resources needed:	Computer
Requirements tested:	25, 26, 34, 42
Preliminary schedule:	2011-11-01 to 2011-11-16
Preliminary responsible:	TA, JK, GA

Test 9: Controller and trajectory planner working together

Objectives:	Controlling the robot when moving the robot along a straight path Controlling the robot when the motors go from one set of angles to another
Achievements:	Working controller Working trajectory planner
Tasks involved:	Define for each motor 5 different joint angle targets Calculate the step response for the motors with the trajectory planner Measure the step response on the angles of the robots motors Compare the calculated step response against the measured Define 10 different target positions Simulate the tool moving to the target position Measure the angles of the robot when moving to the target position Compare the simulated values and the measured ones
Test criteria:	Overshot for a step in desired joint angle should not exceed ±10%(priority 1) or ±5%(priority 2) at least 10 times in a row. The stationary error in the joint angles should not exceed ±10%(priority 1) or ±5%(priority 2) at least 10 times in a row. The overshot for at movement when moving from A to B should not exceed ±10%(priority 1) or ±5%(priority 2)at least 10 times in a row, when moving with maximum speed. Deviation from the trajectory should be less then ±10%(priority 1) or ±5%(priority 2) at least 10 times in a row.
Resources needed:	Computer Robot Trajectory planner Controller
Requirements tested:	25, 26, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 41
Preliminary schedule:	2011-11-01 to 2011-11-16
Preliminary responsible:	TA, JK, VI

Test 10: Alternative control of the robot

Objectives:	Controlling the robot with a joystick (priority 2) Controlling the robot with voice control (priority 3)
Achievements:	Trajectory planer takes input from joystick Trajectory planer takes input from voice input
Tasks involved:	Steer the robot up, down, left, right, forward and backward at least 5 seconds and measure the result Speak to the robot and measure the result
Test criteria:	The robot steers in the given direction with at least 25% speed when using the joystick The robot does as told when spoken to
Resources needed:	Computer Robot Trajectory planner Controller
Requirements tested:	40, 43
Preliminary schedule:	2011-11-01 to 2011-11-16
Preliminary responsible:	TA, JK, VI

4 Summary of tests

A summary of the tests are presented in Table 1. In Table 2, an overview of all tests that need to be passed for each requirement is shown.

Table 1: Summary of the tests.

Test number	Requirement tested	Preliminary schedule
Test 1	9, 10, 17 , 18	2011-10-24 to 2011-10-28
Test 2	9, 10, 17 , 18	2011-10-24 to 2011-10-28
Test 3	22	2011-10-24 to 2011-10-28
Test 4	23	2011-10-24 to 2011-10-28
Test 5	11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21	2011-10-15 to 2011-10-31
Test 6	24	2011-10-15 to 2011-10-31
Test 7	25, 27, 28, 29, 30, 36, 37	2011-10-15 to 2011-10-31
Test 8	25, 26, 34, 42	2011-11-01 to 2011-11-16
Test 9	25, 26, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 41	2011-11-01 to 2011-11-16
Test 10	40, 43	2011-11-01 to 2011-11-16

Table 2: Overview of all test that needs to be passed for each requirement. Requirement number 1-8 are not taken into account in this document.

Number (Priority 1)	Test needed	Number (Priority 2 and 3)	Tests needed
9	1, 2	19	5
10	1, 2	20	5
11	5	21	5
12	5	36	7, 9
13	5	37	7, 9
14	5	38	9
15	5	39	9
16	5	40	10
17	1, 2, 5	41	9
18	1, 2, 5	42	8
22	3	43	10
23	4		
24	6		
25	7, 8, 9		
26	8, 9		
27	7		
28	7		
29	7, 9		
30	7, 9		
31	9		
32	9		
33	9		
34	8, 9		
35	9		

5 Appendix A - Test protocol

Test nr:

Date and place:

Test manager/-secretary:

Description:

Approach:

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Test result: [ ] Pass [ ] Fail

Comment:

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Signature by participants:

[ ] Reviewed by project Test manager

References

[1] AG, VI, AP, *Requirements specification*, TSRT10: Modeling and control of an industrial robot project, 2011.