Compliance compensation and external control of a Gantry-Tau robot

A summery of a Master thesis report by Martin Holmstrand and Kristina Silvebåge,
Automatic Control LTH Lund University.

Many robotic applications require high precision of the robot. The common industrial robot has very high precision, but if the robot is affected by external forces the low stiffness of the mechanical structure will result in a large displacement of the tool. By changing the mechanical structure to a parallel structure instead of a serial the stiffness will be greatly increased. The stiffness can be further improved by implementing compensation for the compliance.

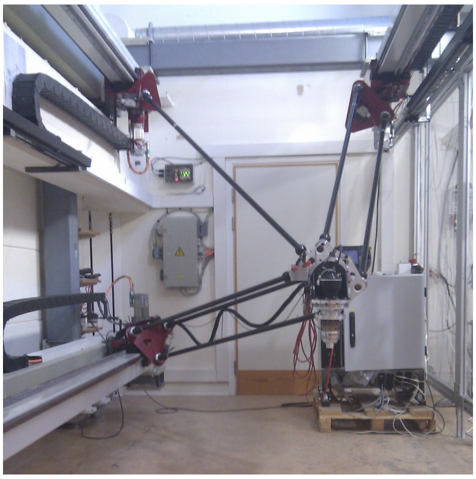

Figure 1: Gantry-Tau robot denoted L2.

Serial and parallel robots

The first robot that comes to most peoples mind when you talk about industrial robots is the common serial type of robot, for example the orange ABB robot. The robot used in for the compensation was a parallel robot of the Gantry-Tau type, see Figure 1. The difference of a parallel robot and a serial robot is that the kinematic chains are connected in parallel instead of in series.

The Gantry-Tau robot

The Gantry-Tau is a parallel robot with the arms configured in three clusters. The number of arms per cart are different and are configured in a 1-2-3 configuration [1]. The basic Gantry-Tau structure of the arms form parallelograms and makes the end effector to have a constant orientation, meaning that the tool can not rotate.

Stiffness

To be able to compensate for the compliance of the robot a mathematical model of the stiffness is needed. By modeling the arms of the robot as springs a physical model with a clear connection to reality is made [2]. The model can be extended by including more of the mechanically weak parts of the robot, in the model used the carts were modeled as springs in the di-

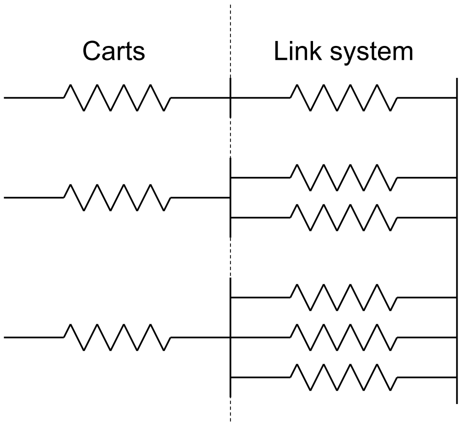

Figure 2: Spring model of the carts and the arm system.

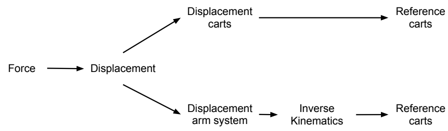

Figure 3: Compensation of the carts and the arm system and how to obtain the reference to the motors.

rection of their guideways, see schematic overview of the model in Figure 2.

With a model of the stiffness by measuring the compliance of the robot can be measured while a known force is applied to the tool. With a known stiffness the compliance can be compensated for.

Compliance compensation

The compensation for the compliance can be divided in two parts.

The compensation for the compliance of the carts when applying a force was measured and a reference could be send to the drivers to move the carts in the opposite direction of the cart movement.

The other part is to compensate for the compliance in the arm system. When the compliance for the arms was measured the compensation for the cars were active to be sure that the compliance of the cart did not affect the measurement. Then by using the inverse kinematics of the robot references could be sent to the carts, see Figure 3. Inverse kinematics is when one know the position of the end-effector, were the tool is placed, and one want to determine the positions of the joints on the carts.

For doing the compensation one have to know the applied force and the compliance. A force sensor was mounted on the tool center point and Heidenhain length measuring gauges, measuring the compliance, was first mounted on the rails obtaining the spring constant of the carts. Then they where mounted at the end of the parallel arm system measuring the Cartesian displacement. Obtaining the spring constant for each arm.

External communication

The control system of a robot sets the limitations of what the sensors and external signals are possible to use. The Automatic Control Department at LTH has developed with ABB an external interface to their latest robot control system, the ABB IRC5 [3]. This possibility to also implement custom algorithms to did not exist on the largest Gantry-Tau prototype at LTH. Therefore more information about the control system was gathered and a program running on the computer controlling the robot enabling external references and information form the drives to be sent by a realtime TCP/IP connection.

Result of compensation

In Figure 4 can one see the displacement of the the tool center point in x direction and the corresponding force when no compensation is active. In Figure 5 force is applied and the compensation is active. The displace of the tool center point is lower. The tests for the compensation was only preformed in homing position and in no other place in the robots workspace.

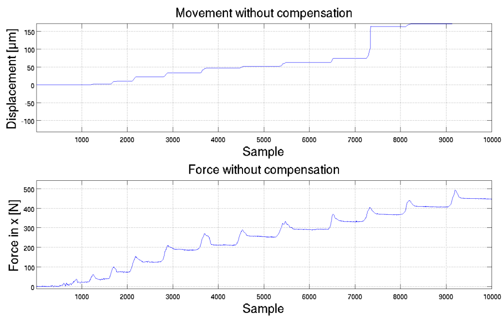

Figure 4: Displacement in x direction without active compensation.

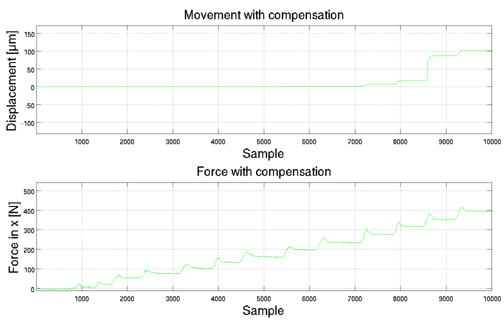

Figure 5: Displacement in x with active compensation.

References

[1] Dressler, Isolde, *Modeling and Control of Stiff Robots for Flexible Manufacturing*, 2012.

[2] N. Ciblak, H. Lipkin, *Synthesis of Stiffnesses by Springs*, 1998.

[3] Blomdell, Anders and Dressler, Isolde and Nilsson Klas and Anders Robertsson, *Flexible Application Development and High-performance Motion Control Based on External Sensing and Reconfiguration of ABB Industrial Robot Controllers*, 2005.