Robot calibration using passive constraints with embedded sensing

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Today's industrial robots that are used in demanding applications, such as in the automotive industry, need to be very accurate. When the accuracy provided by the robot manufacturer is not enough, the robot can not immediately be deployed to its designated task. Since variation are individual, the programmed path coordinates then have to be manually checked and corrected for each robot. This procedure is called "touch-up", which is a very tedious and time-consuming task. If the need for touch-up is reduced with a robot that moves accurately, a lot of time and money can be saved.

One way to reduce the need for touch-up is to calibrate each robot individual and increase the motion accuracy by means of control. Many of the existing methods for robot calibration rely on measurement systems using laser or 3D cameras, which are expensive. An alternative to very precisely measuring the robot when calibrating is to know its position by other means, which can be done by attaching the robot to a rigid mechanism that forces the robot to a certain position, or a certain path. But methods that force the robot to some path have turned out to be very sensitive to disturbances. However, by adding sensors measuring the robot position along the path the calibration can be improved, which were shown in simulations where the sensitivity to, for example, backlash in the robot gearboxes was reduced.

The chosen method for forcing the robot to a certain path is to attach it to the floor via a rigid bar, with a ball joint on each end, which can be seen in Figure 1. The rigid bar forces the robot to move along the surface of a sphere with a constant radius. By adding some angle sensors to the ball joints it is possible to know where on the sphere the tip of the robot is, instead of just that it is on the sphere. This information can be used along with the information from the robot's internal sensors, which is information about where he robot thinks its tip is. With an uncalibrated robot the position where the robot thinks its tip is and the position calculated using the angle sensors on the bar do not match. By formulating a minimization problem for some points on the sphere it is possible to minimize the error between the robot guess and the estimate using the added sensors, by adjusting the geometrical robot parameters. The resulting geometrical parameters differ slightly from the ones specified by the robot manufacturer, and are the ones that are used for calibrating the robot. The minimization is done using a computer, and even if the functions used can be described in a couple of sentences the written out expression would cover about 40 A4-pages.

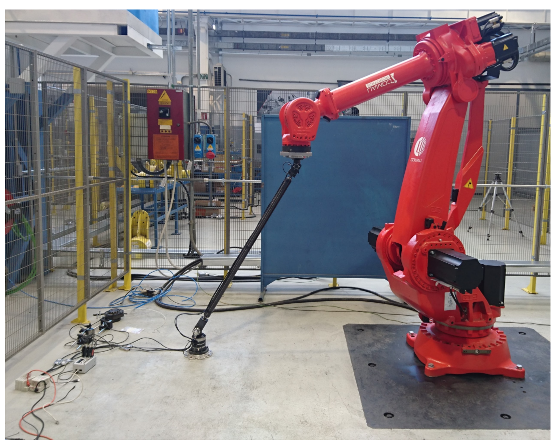

Figure 1: The experimental setup where the double ball-bar with angle sensors is attached to a Comau robot.

The information from the angle sensors on the bar is collected using special hardware, and is afterwards synchronized with the robot's logging of its internal angle sensors. This synchronization turned out to be very important to be able to use the angle sensors for improving the robot calibration, compared to not using the additional angle sensors on the bar. However, the synchronization technique used turned out to have too poor precision to be able to produce fully satisfactory calibration results. With further work on the method, and specifically the synchronization, it should be possible to achieve precise and robust robot calibration, without the need of expensive instruments.

For the full thesis report, refer to:

Brand, S and Nilsson, N. (2016). *Calibration of robot kinematics using a double ball-bar with embedded sensing.* Master Thesis Report, ISSN: 0280-5316. Department of Automatic Control, LTH, Lund University, Sweden. Available at http://www.control.lth.se/publications/