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CALIBRATION TRENDS IN INDUSTRIAL ROBOTICS

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Abstract: A survey of calibration techniques was purpose of this article together with kinematic explanation of industrial robot with aim to obtain and implement any of them that are prohibitive for common calibration operations. Each method, if is proven accurately will be a desirable as low-cost solution to real time robot positioning problems. These factors lead us to the fact that better approach of implementing consists in real timing in process calibration. Calibration trends are moving away from older calibration processes, because instruments are more user-friendly and results that previously required long specialized procedures can now be achieved by adopting by right technology.

1 Introduction

Calibration trends are moving away from older calibration processes, because instruments are more user-friendly and results that previously required long specialized procedures can now be achieved by adopting by right technology. Motion control of calibration will be implemented on the basis of information obtained from sensors placed directly for drives of industrial robot, as well as the sensor working environment according to the specific requirements for each application [1], [2].

The identified parameters related to robotics calibration are accuracy, repeatability, and resolution. Each of these depends on the various components used (links, motors, encoders, etc.), the construction procedure, the capability of the controller and programming method (online, offline) [3]. Resolution is defined as the smallest incremental move that the robot can physically produce. Repeatability is a measure of the ability of the robot to move back to the same position and orientation. Accuracy is defined as the ability of the robot to precisely move to a desired position in 3-D space [4]. The example of calibration process can be seen at fig. 1.

2 Kinematic calibration

A robot kinematics structure is often represented mathematically using a compact representation of the position and orientation of each joint relative to the previous joint. For demonstration purposes, the modified Denavit-Hartenberg (DH) notation as presented in next section will be used.

2.1 Creation of kinematic model

First of all, it is necessary to create a kinematic model of the robot, which is the mathematical expression of the robot geometry and its movements [5], [6]. There are several different ways to build a kinematic model. The most popular method is the method introduced by Denavit and Hartenberg. The principle consists in creation of coordinate systems for each common axis. This method follows the following specific parameters, D-H parameters, fig. 2.

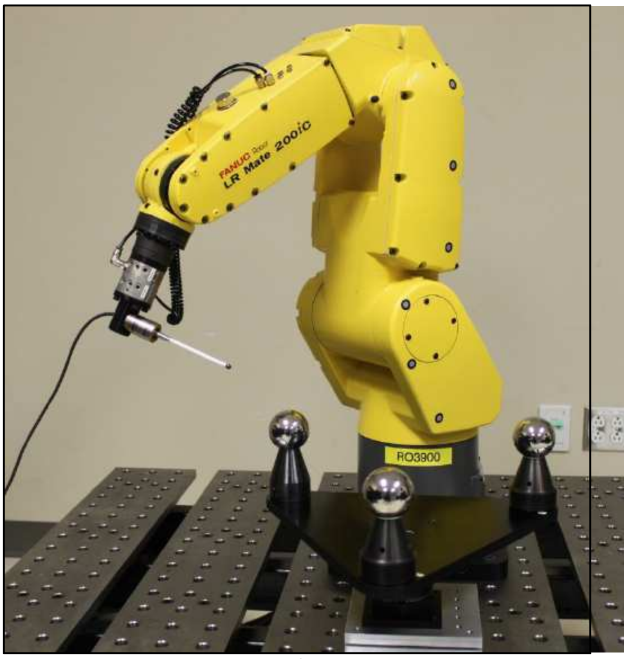

Figure 1 Example of calibration process

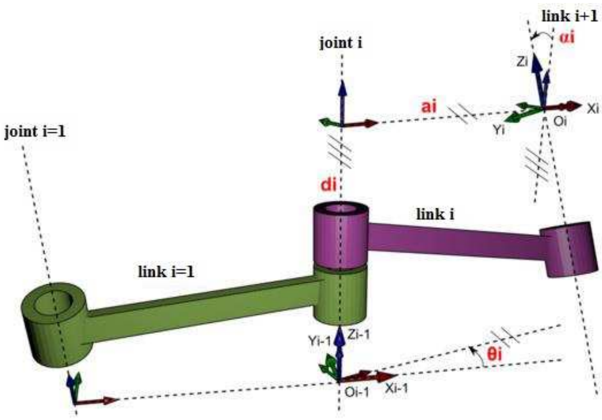

Figure 2 D-H parameters

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Table 1 Describtion of parameters

d_i	Moving along the previous Z axis after common normal
θ_i	The angle of previous axis X with respect to new axis X
a_i	Length of individual links
α_i	Angle of previous Z axis with respect to new Z axis

Each coordinate system is interconnected by the D-H parameters, which makes it possible to create a homogeneous transformation matrix [7]. This homogeneous transformation matrix represents the relationship between two consecutive links. These matrices are then multiplied to form a relationship between the robot base coordinate system and the end effector coordinate system. An industrial robot can be used, for example, in control applications to reduce potential human factor failure [8].

2.2 Measurement methods

The second step of kinematic calibration is to obtain the end effector coordinates. These coordinates can be determined by measurement them by using different methods.

Mannual calibration represents the easiest way to achieve the required robustness of the robot. Most companies engaged in the production of industrial robots and manipulators develop their own manual calibration methods for the robot. These methods are easy to handle and to necessary equipment.

Force control calibration method is designed by ABB and is only usable for industrial robots from this company that are compatible with this method. The system monitors the force exerted on the object by using external sensors (Fig. 3). In other words, the robot feels how much force he applies to the object. The control system is able to detect the position of the used tool automatically.

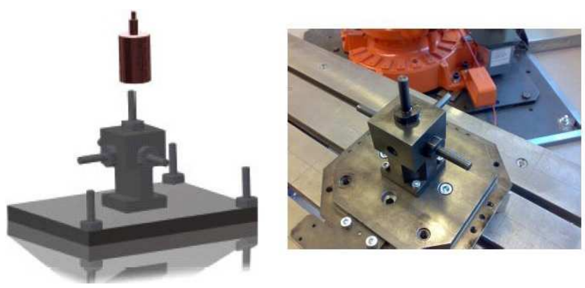

Figure 3 External sensor during the force control method

Navigation calibration method is an automated, very accurate calibration method. The principle lies in the positioning of the spherical object (Fig. 4), which is mounted on the robotic arm. The control system automatically positions with the calibration device in the direction of the individual axes to the fixed spherical object that coordinates we know.

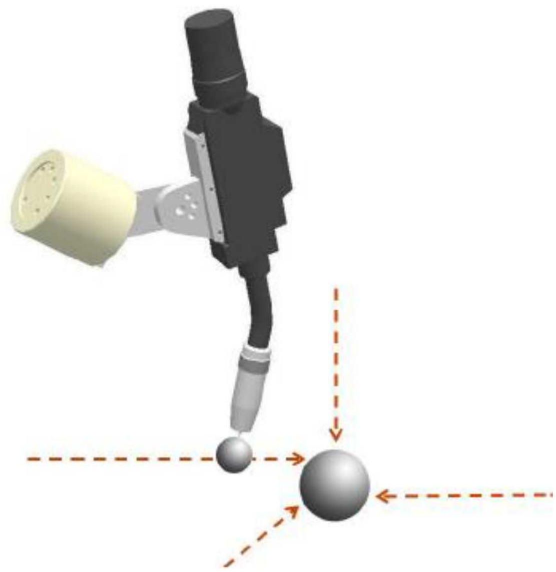

Figure 4 Navigation method of static calibration

3 Trends

The LaserLAB calibration system is a measuring system consisting from a five-angled measuring sensor with five laser measuring sensors, measuring gauges and necessary software for robot calibration. Usage is found in all modern robotic production and non-production processes [9]. The LaserLAB calibration system can be used for multiple cells, not for a stationary system.

If the measuring ball is placed by the robot into the measuring system space, system calculates position of the center of ball. It is important to keep in mind that in the close of the robot there is also operator, so security first is necessary [10]. Thanks to direct core center correlation of tool center point (TCP), it is possible to measure robot. Fig. 5 presents LaserLAB calibration method.

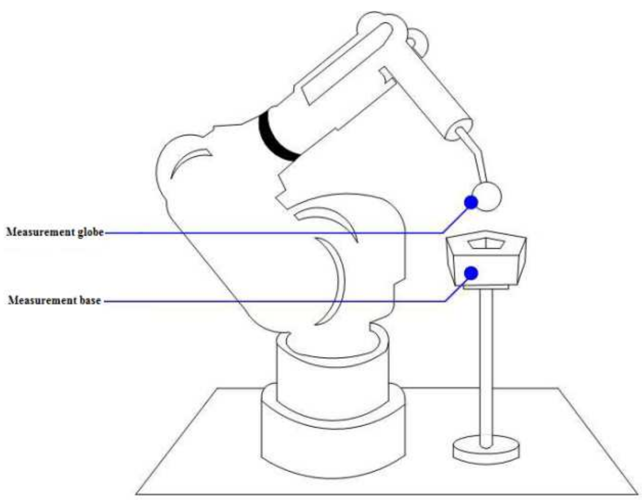

Figure 5 Calibration by LaseLAB system

LaserLAB calibration method consists of two hardware components, namely a pentagonal measuring sensor and one or more measuring globes. In addition, other measuring tools such as, for example, bars that help measure, for example, electrode holders. Depending on the measurement or calibration tasks, LaserLAB works with various software that allow you to measure the robot tool, the base, the robot itself, the temperature influence of one device based on servomechanisms [11]. LaserLAB allows:

- perform all measurements with one system,
- automated non-contact measurement,
- robot calibration directly inside the production cell,
- simple operations performed by the operator,
- reduce downtime to a minimum,
- compatible with most commonly used robots (ABB, KUKA,...),
- mobile and flexible use.

Programs tools contains in LaserLAB system:

Tool measurement with TOOL-IN: The aim of the measurement is to determine the center point of the tool. Measurement output is the real geometric dimensions of the tool in 3 as well as in 6 dimensions.

Measurement of robot by LOOP-IN: The aim of the measurement is to improve the positioning accuracy. Output is the exact model of the robot axis according to " Closed-Loop Calibration Method" (calibration method of closed loop).

Measurement of cooperating industrial robots by KIR-IN method: The goal is to measure one or several other co-operating robot axes. The output is a common coordinate system in which the kinematics move.

Measurement of base by BASE-IN method: The goal is to determine the transformation from the workpiece to the robot coordinate system. The system performs a component holder measurement, or external and stationary tools.

Measurement of temperature influence by TEMP-IN method: With LaserLAB a TEMP-IN is possible continuously measure the effect of temperature and immediately compensate it inside the robot - without stopping operation.

Measurement principle by LaserLAB system can be seen at fig. 6.

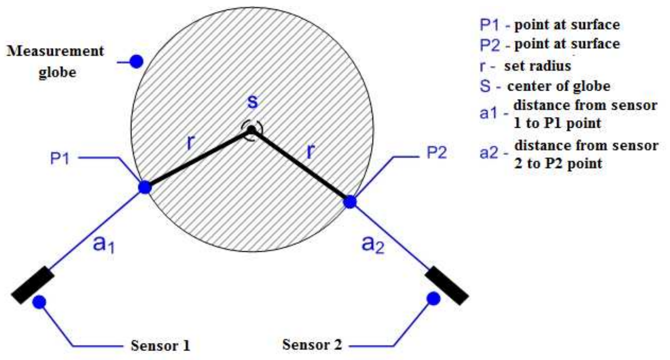

Figure 6 Measuring principle by LaserLAB system

Multiple one-dimensional measurement of distance for measuring globe forms as reliable basis for non-contact measurement of coordinates. Measurement by using five LaserLabs laser sensors is performed so that their rays from different directions meet in a common center [12]. The laser beam directions are determined by the company's calibration.

Surface points on the globe can be determined in three dimensions according to the directions and measured distance from individual sensors. Because of this information, the center of the ball can be calculated. The first approximation for TCP is obtained after four measurements. Further measurements can be obtained by rebalancing spheres within LaserLAB. The rule is that 12 measurements are sufficient to achieve a high enough accuracy [13].

4 Conclusion

From the selecting point of view is possible to choose an individual calibration methods, it is advisable to use several methods because they can be applied to most industrial robots. Static calibration is less time consuming for a small number of robots that need to be calibrated, since each robot needs to be calibrated separately, which will significantly affect the overall calibration time.

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