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# 3D metrology using a collaborative robot with a laser triangulation sensor

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**Abstract**

Industrial robots are a key element in Smart Manufacturing systems. They can perform many different tasks such as assembly, pick-and-place, or even 3D metrology operations. In order to perform 3D metrology, the robot is equipped with a 2D laser triangulation sensor. The accuracy of the measurements made by this system is dependent of an accurate TCP (Tool Centre Point) calibration and the accuracy of the robot. In this paper, a TCP calibration method is applied to a collaborative robot. The hand-guiding feature of this kind of robots is used to establish a human-robot interaction to obtain the laser sensor TCP using a calibration sphere. Experimental results are presented to validate the procedure and evaluate the quality of the measurements.


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*Keywords:* TCP calibration; Collaborative robot; Hand-guiding; Human-robot interaction; 2D Laser triangulation sensor; 3D metrology; Calibration sphere.

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## 1. Introduction

Industrial robots have an important role in automated manufacturing of vehicles, aircrafts and even robots themselves. *"Cobots"* (collaborative robots) are the new era of industrial robots and their use is increasing in every type of industry.These robots represent interesting properties in the industrial field:

- they do not need safety fences around them like traditional industrial robots
- they allow teaching robot paths by manual guidance (hand-guiding).
- the possibility to an operator to interact with the "cobot" to lighten charges and with that improve the operators' ergonomics conditions.

In fact, at the beginning of this new generation robots, they were mainly used as weight compensators [1]. They are now used in many other applications such as pick-and-place operations, assembly lines and also as a quality control tool. One of the new applications is to perform measurements as a 3D metrology system. This application will offer great flexibility to the industry. Some years ago, to measure with precision some objects it was necessary a specific 3D measurement system like a Laser Tracker [2], metrology arms or a CMM (Coordinate Measuring Machine) [3]. These specific measuring tools offer very good results, but they can only be used to metrology purposes [4].

A collaborative robot can be considered as a universal machine, which can for example, in the same robotic cell, measure objects, pick tools to perform different operations or even take workpieces to assemble [5]. In addition to this, the collaborative robots allow an interaction between the human and the machine. One of the examples of collaborative robots is the Kuka LBR iiwa 14 R820. This robot is a seven-joint robot equipped with torque sensors in each of its joints. This allows not only to detect any contact with the robot body (safety feature), but also to monitor the efforts of an assembly application (process feature). The torque sensors can also be used to measure the efforts on each joint allowing an online position error correction [6].

One of the most important aspects to consider for this metrology application is the accuracy of robots. In terms of accuracy Kuka iiwa robot can produce a position error of 2,5 mm which can be a drawback for 3D metrology applications [6]. There is a set of factors contributing to this accuracy problem: geometric and nongeometric factors [7]. The geometric ones consider the geometric parameters, the joints offset and the TCP definition [8]. The origin of these deviations is the manufacturing process of the robot, which means that the real geometry of the robot components does not match the previously designed and projected geometry [9]. In addition to this, gearboxes and transmissions can produce errors due to its backlashes and its manufacturing errors too. The nongeometric errors are mostly dependent of the robot configuration. These errors are caused by the compliance of the robot links and joints, gearboxes backlashes, kinematic errors, encoder resolution and thermal effects [10].

TCP calibration is one of the important aspects concerning robots' accuracy improvement. Classical methods of this calibration consist on using a special cylindrical-type pointer to record at least three non-collinear TCP positions changing the orientation of the robot touching always the same single point in the robot workspace [11]. Some work has been done to obtain the TCP using contactless technologies such as laser sensors. In [12], a methodology is applied to a standard sphere with the particularity of comparing all the robot positions to a single reference position. Another work [13] is performed to obtain the TCP in an inverse way, as the laser sensor is fixed on the robot workspace, independent from the robot and the calibration sphere is held by the robot.

In this paper, the TCP identification of a 2D laser triangulation sensor with a collaborative robot is demonstrated. In the next section, the methodology of obtaining the TCP is described. Section III presents some experimental results to validate the method previously described. Finally, in Section IV all the conclusions about this study are exposed.