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Easy industrial robot cell coordinates calibration with touch panel

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ABSTRACT

Robot cell calibration is the basic commissioning task in robot applications. Traditional way is either tedious manual calibration or complex machine calibration with expensive sensors. This paper presents a novel solution to complete the robot cell calibration with touch panel, which is an easily accessible and low-cost device in daily use on tablets or smart phones. In this paper, we discuss the robot cell calibration problem and propose the touch panel based calibration system approach. In particular, the error effect of touch panel on calibration has been analyzed. The practical calibration performance has been validated via experiments.

1. Introduction

For position based industrial robot programing, calibration of the robot cell coordinates is the basic commissioning task [1]. A proper robot cell calibration is essential for accurate robot motion by ensuring the coordinate relationships between robot and its peripherals (e.g. end-effector, fixture, and tray) in a robot cell. It enables the offline robot programing by aligning the coordinates from CAD model to the physical cell. Moreover, cell calibration can reduce the reprograming effort if the relative position between robot and peripherals gets changed in a collision crash, in transportation, or after maintenance.

Traditional cell calibration is to jog a robot manually to approach sharp tip features with different robot poses [1]. It is tedious, time consuming and operator-dependent, since it requires careful eye observing for tips alignment. Usually, it can easily take a skillful engineer half hour to reach a proper cell calibration. Therefore, It takes considerable engineering time and effort in robot cell setup, recovery, and duplication, where robot cell calibration is mandatory for proper robot path programing.

Thus, designing an automatic robot cell calibration solution attracts the interest of researchers from both academe and industry. The prior art of automatic robot cell calibration presented solutions via mechanical constraint [2,3], vision processing [4–14], and optical sensor measuring [15–21]. In particular, mechanical constraint based cell calibration takes the advantage of geometry features such as a plane, a sphere, or a line. The calibration accuracy is guaranteed by the mechanical part machining. Force control or compliant motion is need to touch the geometry features with a triggering signal [14]. Thus, this cell calibration solution requires complicated robot control, and is not efficient with considerable robot motion time to detect the geometry features.

Vision or optical sensor based calibration has the advantages of non-contacting and direct measuring on robot peripherals. Watanabe et al. [10] presented a robot cell calibration method based on vision measurement, which requires neither specific camera attachment location nor other additional equipment. Liu et al. [12] proposed a TCP automatic calibration method, which is based on binocular vision measurement. It can reduce errors coming from contactless measurement and overcome the slowness of vision system. However, vision based calibration is affected by environment and is not capable to reach high accuracy with the limit of camera.

Compared with camera, optical or laser sensor can reach of higher accuracy with larger measuring range, and more reliable to environment. Zhu et al. [18] proposed a calibration approach for robot tool center point using a laser displacement sensor. It is robust and the calibration error is reduced significantly. One famous optical sensor based calibration solution is the Bull's Eye [19] implemented in ABB robot welding application. which uses a single laser beam as a line constraints to calculate robot tool coordinates. However, it does not cover the work object calibration which is critical for assembly applications.

For better engineering efficiency and excellence, ABB Corporate Research in China initiated robot calibration related research since 2013, and proposed an improved cell calibration solution by combining optical sensor with mechanical constraints [22,23]. For the first time, it automates robot tool and work object calibration with a cross beam sensor and a linear touch sensor. This approach reduces the manual cell calibration time and effort by more than 50%. However, due to the

Abbreviations: w.r.t., with respect to; TCP, tool center point; Wobj, work object coordinates.

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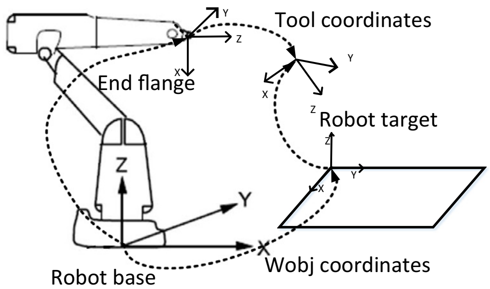

Fig. 1. A scheme of robot coordinates system in a cell.

optical beam searching and geometry feature detecting procedure, this calibration solution requires certain time and cell space for robot motions. Moreover, the involved sensors are still not as easy as plug-and-play. Considerable efforts are needed for mounting and connecting them into a robot cell.

In this paper, we propose an easy and efficient robot cell calibration solution with touch panel as the measuring sensor [24]. Comparing with existing solutions, it is easier, faster and cheaper to perform industrial robot cell calibration, since a touch panel is widely used in consumer devices like tables or smart phones. In particular, the problem of robot cell calibration are discussed while the novel calibration system and method are presented. In order to clarify the usability of commercial touch panel for industry purpose, the touch panel error effect on the robot cell calibration are analyzed via simulations. Furthermore, experiments are carried out to validate the error analysis and performance of the proposed robot cell calibration.

2. The problem of robot cell calibration

The purpose of a robot cell calibration is to identify the coordinate relationships between an industrial robot and its peripherals. As illustrated in Fig. 1, the coordinates of a tool and a work object have to be determined for programing a robot target w.r.t. (with respect to) an object with a dedicated tool. In particular, the tool coordinates are defined w.r.t. robot end flange. The work object (Wobj) coordinates are defined w.r.t. robot base. The origin of the tool coordinates is the so-called TCP (Tool Centre Point), which is the active point for approaching the target in space. The origin of robot end flange is usually considered as TCP0.

Benefits of robot cell calibration are summarized as:

- Achieving proper robot target accuracy
  This is especially important for offline programing where the programmed robot targets are transferred from virtual cell to physical cell. The eventual robot target accuracy is not only depending on the cell coordinates but also the robot internal coordinates (i.e. kinematics of the manipulator). Usually, a robot itself is not perfectly accurate. Cell calibration cannot eliminate the internal error from robot, but can partially compensate and linearize it in a local working area.
- Assisting robot programing
  This is the very benefit for easing the robot programing with tool reorientation and work object orientation aligning. Concretely, a proper tool reorientation requires the robot to reach the same position with different tool orientations, which is significantly depending on the translation accuracy of TCP. A proper work object orientation aligning requires the robot to move along correct directions w.r.t. an object, which is depending on the orientation accuracy of work object coordinates. In addition, proper tool reorientation and work object aligning performance are also preconditions in vision guided robot programing.
- Recovering robot targets
  If all the robot targets are programmed w.r.t. calibrated cell coordinates, targets can be easily recovered from any change of tool or object via recalibration rather than reprograming. It is especially important for robot tasks with huge programing effort.

The above summarized benefits of robot cell calibration can play different importance under different robot programing methods, as summarized in Table 1, where typical robot programing methods are:

- Pure manual teaching, where the targets are taught manually by human observing. Therefore, it does not require well calibrated robot system (i.e. tool, Wobj, kinematics) to reach the desired robot targets. However, proper TCP and Wobj can significantly reduce the programing effort in manual teaching.
- Manual teaching with offsetting, where key targets are taught while others are generated via coordinate calculation. Therefore, it requires suitable robot system accuracy in offset targets generation. Cell calibration also plays an important role to assist the key target teaching.
- Offline programing, where the robot targets are programed in an offline environment with a virtual cell. Therefore, it requires high accuracy of robot system to align virtual and physical coordinates. In ideal case, no manual programing effort is involved.
- Vision guiding, where the robot targets are given by a vision system. Therefore, it requires high alignment of robot and vision coordinates system. Similar to offline programing, manual programing effort is not involved.

In summary, robot cell calibration is essential in robot applications with typical programing methods by either ensuring the accuracy or easing the programing.

3. The proposed system for robot cell calibration

Touch panels are widely used for HMI (Human Machine Interface) purpose in mobile devices such as tablets and smart phones. The touching technology of touch panel with trends of more sensitivity, and higher resolution, can be suitable for position measuring purpose. Comparing with existing industrial measuring devices with laser, vision or encoder, touch panel is much cheaper and easier assessable.

There are various touching technologies [25] applied on touch panel such as resistive touching, capacitive touching, and EMR (Electro-Magnetic Resonance) touching. Typical touch panel performances in existing mobile device are listed in Table 2. In particular, accuracy at full measuring range is evaluated by experiment with a planar coordinate device in the laboratory of ABB. The error distribution of the evaluated touch panel is quasi linear. It is worth noting that EMR touching provides higher resolution and accuracy compared with capacitive touching, since the WACOM device is for digital drawing purpose.

As illustrated in Fig. 2, the proposed robot cell calibration system is composed of an industrial robot, a touch probe mounted on robot, a touch panel arranged in the workspace of robot [24]. It is preferred that the touch panel is integrated in a device with its own calculation power and communication capability, which is already available in commercial mobile devices. So that, the touch panel can synchronize with robot controller via communication. By monitoring the touching status, the robot can proceed the cell calibration motions and calculations automatically. In particular, considering communication delay, robot motion speed will be slowed down in approaching the touch panel. For instance, with the typical communication delay within 10 ms via WIFI, an approaching robot speed at 2 mm/s can stop the robot motion properly with only 0.02 mm overshoot introduced. Such a small overshoot of the robotized touching will not damage the touch panel nor affect the calibration accuracy.

It is worth noting that the proposed system calibrates the tool coordinates of a touch probe and the work object coordinates of a touch panel. For practical use in a robot cell, mechanical adapters are needed for mounting the touch probe and touch panel. As illustrated in Fig. 3, the touch probe can be attached to typical robot tools like finger grippers