

Benchmarking Robot and Cobot Performance for an Assembly Application

Markus Gapp¹, Anke Fischer-Janzen¹, David Pfister¹, Thomas M. Wendt¹, Stefan J. Rupitsch²

¹ University Offenburg, Badstrasse 24, 77652 Offenburg, Germany,

² University Freiburg, Institut für Mikrosystemtechnik – IMTEK, Georges-Köhler-Allee 201, D-79110 Freiburg, Germany
markus.gapp@hs-offenburg.de

Summary

Over the past decade, the popularity of cobots (collaborative robots) has grown, largely due to their operator-friendly usage. When selecting a cobot or robot for a specific application, it is essential to consider which model best aligns with the desired process. The objective of this work is to introduce a method for evaluating the three-dimensional position performance of a given process to identify the optimal technical solution.

Keywords: Cobot, Robot, 3D-accuracy, Performance, Optical metrology

Introduction

The evaluation of robot performance must be conducted according to the ISO 9283:1998 standard [1]. Two essential parameters are absolute accuracy and repeatability, both in terms of pose and path. Absolute accuracy will be required when using offline programs or when programming a path. For assembly tasks, repeatability is more important to reliably move to any required process position.

There are ongoing efforts to optimize the evaluation of repeatability of pose (RP) especially for cobots according to their kinematic structure as outlined in [2]. The definition of ISO 9283 allows flexibility in performing repeatability measurements. The aim of this study is to focus on the issue of 3D-pose repeatability using a basic and inexpensive setup of high-precision standard industrial sensors.

Method and system setup

To compare RP, measurements were performed on a 6-DoF cobot (Fanuc CRX10iA) and a 6-DoF robot (KUKA KR16). Unlike [3], both robots were programmed to move from the upper ISO position to the centre of the robot's working range. This reflects our application of picking parts in a defined position while precise positioning. In [4], challenges were found in the precision of pose repeatability measurements. This setup was adapted accordingly. The sensor system was expanded by adding a 1D-laser sensor (OD2000) that measures the Y-coordinate in addition to the laser triangulation sensor (ECCO75.100) measuring X- and Z-

coordinates for the purpose of ascertaining the third dimension. The setup is shown in Fig. 1.

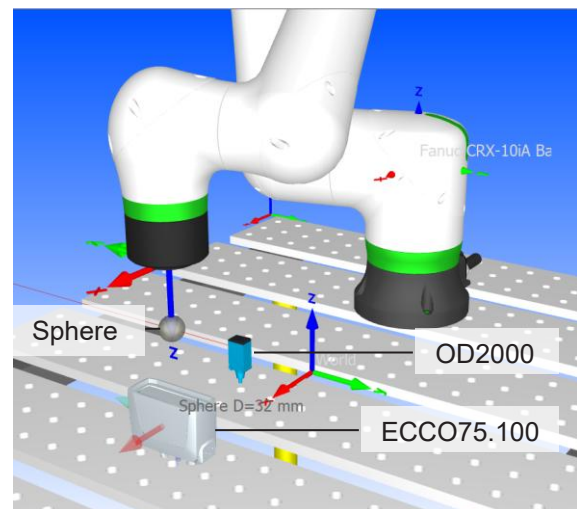


Fig. 1. Robot with sphere assembled at the flange and two laser sensors to detect the 3D-position of the sphere

The measured position of the sphere's centre was utilised for the robot position calculation. In order to facilitate a comparison of the measurement data, the speed and trajectory of the cobot and robot were unified, as required in [1]. The calculation of RP was performed in accordance with [1], utilizing \bar{I} as the 3D mean position and S as the standard deviation.

$$RP = \bar{I} + 3S \quad (1)$$

Results

In the data sheet, the repeatability of the industrial robot is specified as ± 0.05 mm. The repeatability achieved with our system was 0.027 mm ($S \pm 0.006$ mm). In comparison to the reported repeatability of the cobot, which was found to be ± 0.04 mm, we were able to determine a value of 0.037 mm ($S \pm 0.008$ mm).

Fig. 2 shows 30 measurements of the respective axes. The setup was aligned with the axes of the robot's base coordinate system to avoid possible error propagation that might occur during a required coordinate transformation.

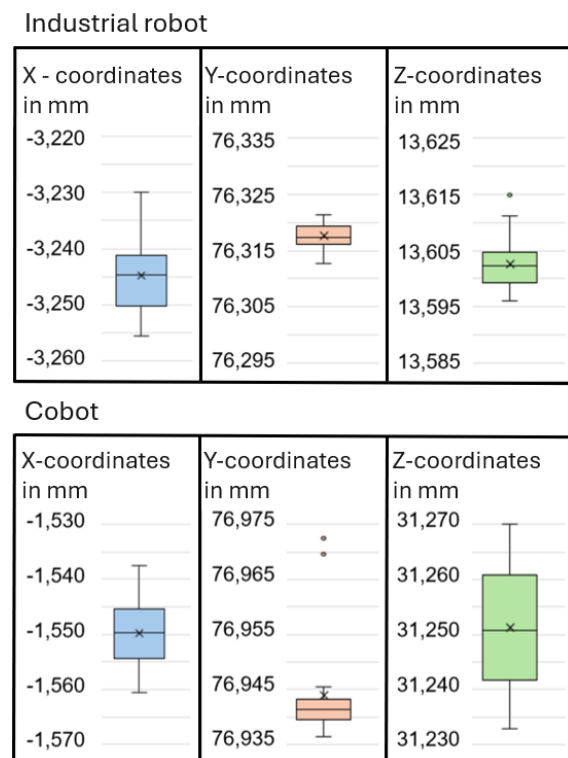


Fig. 2. Distance to sensors over 30 measurements shown in X-, Y- and Z-coordinates in mm. The upper boxplots show the values of the industrial robot and the lower boxplots those of the cobot.

Discussion

In our work, an easy to integrate process for evaluating the 3D position performance for our application has been demonstrated. Both robots are suitable for this application as they achieve the minimum tolerance. Although the test revealed that the industrial robot was more precise, we chose the cobot for our application based on the necessity to collaborate with humans.

The supposedly better repeatability of the cobots [5] was refuted in our test setup. This might indicate more restrictive requirements for purely industrial applications.

It is noticeable that the measured values of the Z-axis of the industrial robot show a significantly lower scatter. This could be due to the control structure of the robot's axes. Looking at the measured values of the Y-axis, there are clear outliers for the cobot. The reflective sphere's surface could also be a possible cause in addition. The potential impact of external factors, e.g. surface reflections, sphere smoothness, and varying loads at the robot flange, should be considered.

It is well known that accuracy critical processes like fitting are easier to realize with a robot. Therefore, additional values to determine the absolute accuracy and repeatability are important depending on the process in question. Table 1 provides an overview of the most important criteria of ISO 9283, which should be focused in further studies.

Tab. 1: Criteria of ISO 9283 as far as absolute accuracy and repeatability are concerned

	Absolute accuracy	Repeatability
Pose	x	x
Path	x	x
Distance	x	x
Multidirectional		x
Exchangeability	x	
Drift of pose	x	x

References

- [1] ISO 9283:1998 Manipulating industrial robots – performance criteria and related test methods, 1998
- [2] M. Hu, H. Wang, X. Pan, Y. Tian, Optimal synthesis of pose repeatability for collaborative robots based on the ISO 9283 standard, *Industrial Robot* 46(6), 812–818 (2019), doi: 10.1108/IR-03-2019-0056
- [3] M. Vocetka, R. Hunady, M. Hagara, Z. Bobovský, T. Kot, V. Krys, Influence of the Approach Direction on the Repeatability of an Industrial Robot, *Appl. Sci.* (2020), doi:10.3390/app10238714
- [4] T. M. Wendt, M. Gapp, A. Fischer, Innovative and cost-effective Measurement Setup to determine Robot Accuracy, *SMSI 2023* (2023); doi: 10.5162/SMSI2023/D4.4
- [5] P. Amiri, M. Müller, M. Southgate, T. Theoridis, G. Wei, M. Rivhards-Brown, W. Holderbaum, A Statistical Analysis of Commercial Articulated Industrial Robots and Cobots, *J. Manuf. Mater. Process* 8(5), (2024); doi: 10.21203/rs.3.rs-3946319/v1