A NEW FULL POSE MEASUREMENT METHOD FOR ROBOT CALIBRATION

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ABSTRACT

Accurate full pose measurements (position and orientation) of robot end-effectors in Cartesian space are frequently required for identifying robot kinematic errors during the calibration process. This paper proposes a new method for measuring the full pose of robot end-effectors for calibration. The features of a set of target points (placed on a rotating end-effector) on a circular trajectory are analysed in this method. The Puma robot's computational simulation results validate the precise measurement. Furthermore, experimental calibration and validation results for the Hyundai HA-06 robot demonstrate the proposed method's effectiveness, correctness, and reliability. This method can be applied to robots that have entirely revolute joints or to robots for which only the last joint is revolute.

***Keywords*: full pose measurement; robotic manipulator; robot calibration.**

1. INTRODUCTION

This study proposes a new method for measuring the full pose of end-effectors for robot calibration. Based on a set of discrete points on a circular trajectory measured by a non-contact 3D coordinate measuring device, this method provides a robot's full pose (e.g., a laser tracker). Laser interferometry devices are widely used due to their high accuracy, quick measurement, large measuring range, and ease of use [14–17]. The trajectory of a target fixed on a robot end-effector (tool) is measured when the end-effector is rotated uniquely; in this way, an arc of a circle and its centre point O located on a rotation axis can be obtained. The z axis of the coordinate frame assigned to end- effector E is determined by an orthogonal vector of the rotation plane

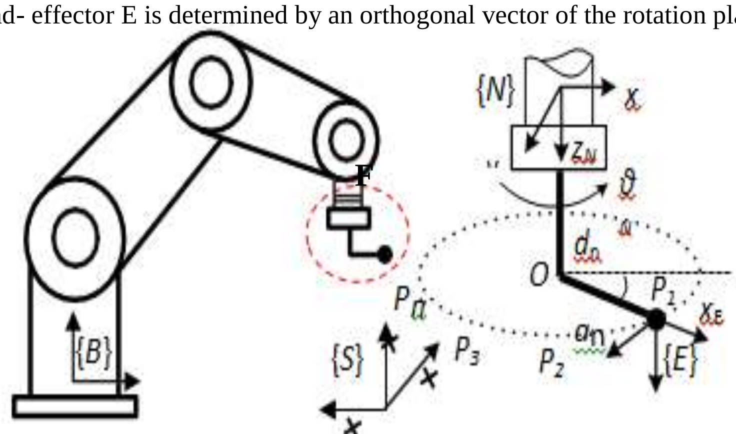

figure1. Basic principle of the measurement method.

(which contains the arc of the circle). The x axis of frame E is determined by a vector connecting an initial point O to a terminal point P1 (Figure 1), and the y axis completes this orthogonal coordinate system. The proposed method takes advantage of the high accuracy of available 3D point measuring devices and can be automated; thus, the method's application is simple, relatively fast, and simple to set up. It also does not employ any specialized tools that incur additional manufacturing costs or necessitate calibration. The measurement accuracy of the method is evaluated by comparing the deviation between two fixed frames E and E' on the robot end-effector, where frame E is computed by the proposed method and frame E' is obtained by robot forward kinematics. The proposed method's accuracy is evaluated using simulation on a Puma robot and demonstrated using experimental calibration on a Hyundai HA-06 robot.

In Section 2, the principles of the measurement method are presented and the plane and center points of rotation are identified. Section 2 presents an evaluation of the measurement accuracy of the method via a simulation on Puma robot, while Section 2 presents experimental calibration results for an HA-06 robot with full-pose measurements obtained by the proposed method. Section 3 presents our conclusions.

1.1 Principle of the Measurement Method

The proposed measurement method must determine two features: the rotation axis of the last robot joint and rotation centre for the acquired position, and the orientation of the robot end-effector (i.e., coordinate frame E) at each robot configuration. The measurement method's fundamental principle is specified in three steps (Figure 1).

1.2Application of the Measurement Method in Practical Calibration

We must first measure the position and orientation of the robot end-effector in order to identify robot kinematic errors. The proposed measurement method was used in an experimental calibration for a Hyundai HA-06 robot in this study.

1.2.1 Kinematic Model of the HA-06 Robot

The nominal model of the HA-06 robot was established by using the D-H convention [21]. Theframes are assigned from the robot base to the end-effector as in Figure.

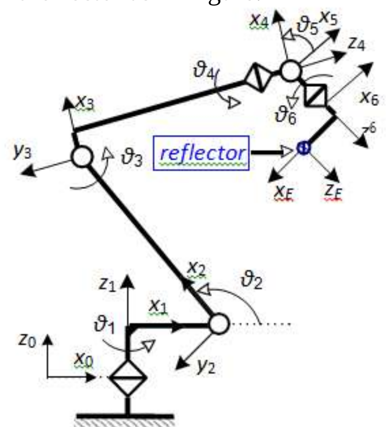

Figure 3. Schematic ofrobotHA-06andattachedlinkframes.

Table 1. Absolute position and orientation accuracy of the robot over these to f56robotposes Q_1.

		Mean Value	Std.	Max. Value
Absolute position accuracy[mm]	Before Cal.	3.6573	1.55090	7.0433
	After Cal.	0.12933	0.06618	0.32229
Absolute orientation accuracy about $x$axis:αEuler angle[deg]	Before Cal.	0.33022	0.18441	0.86927
	After Cal.	0.00864	0.00593	0.02649
Absolute orientation accuracy about $y$axis:βEuler angle[deg]	Before Cal.	0.67187	0.36829	1.4892
	after Cal.	0.01658	0.01164	0.0470
Absolute orientation accuracy about	Before Cal.	1.4004	0.2213	1.7003

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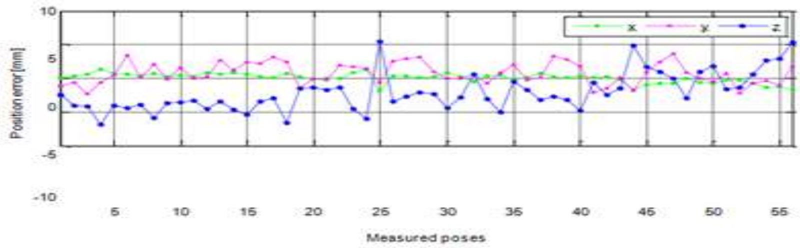
zaxis:γEuler angle[deg]			3	
	after Cal.	0.01286	0.0096 2	0.0452



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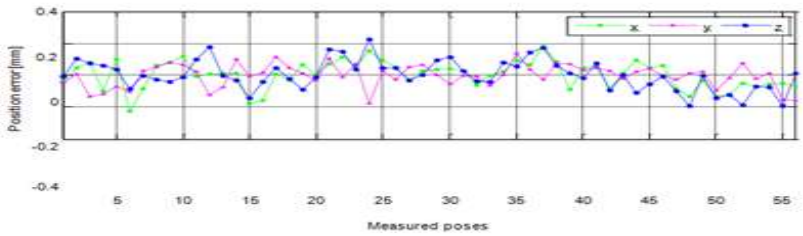

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Figure 4 A. Robot position accuracy before calibration (poseset Q_1) .**B.** Robot position accuracy after calibration (posesetQ_1).

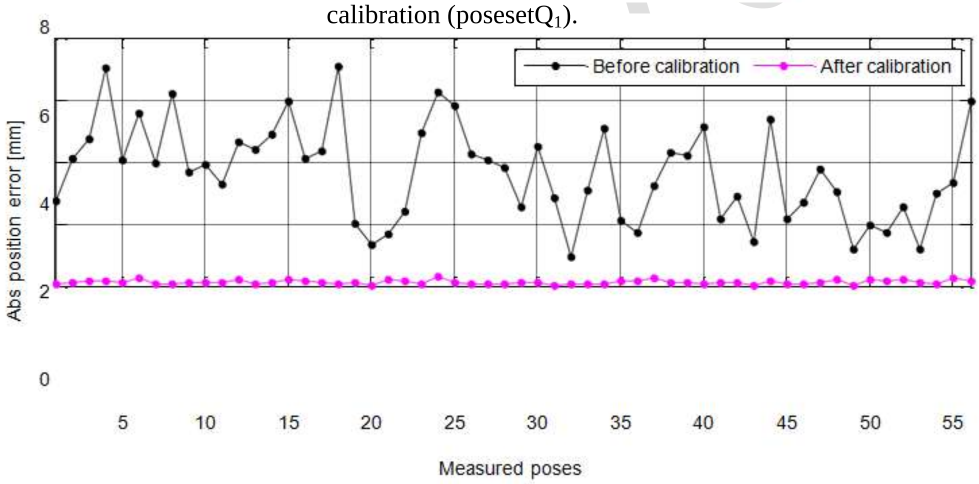
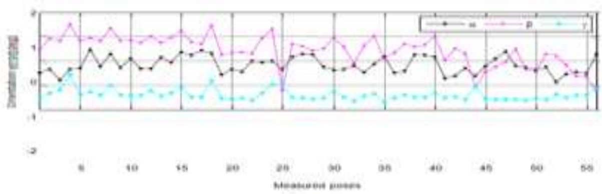


Figure5. Robot’s absolute position accuracy before and after calibration(posesetQ_1).



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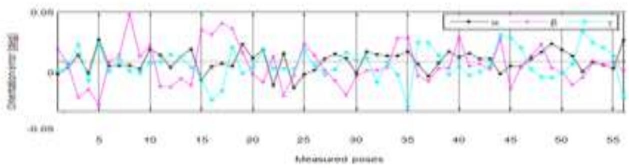

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Figure 6 (A) Robot orientation accuracy before calibration(poseset Q_1). **(B)**Robot orientation accuracy after calibraton (posesetQ_1).

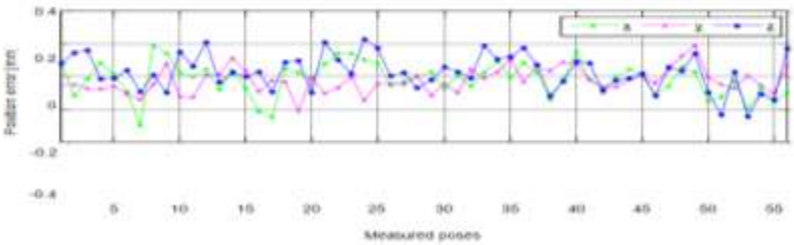

Figure7. Robot position accuracy(validation, poseset Q_2).

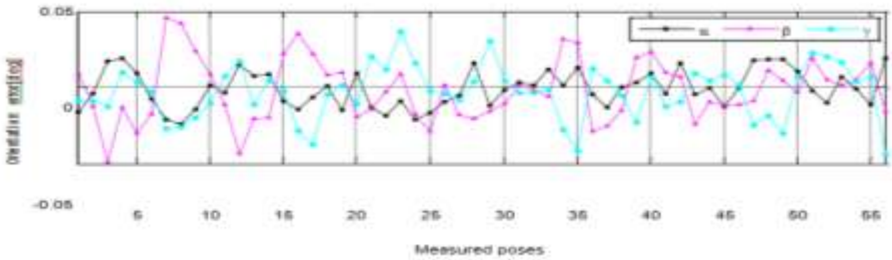

Figure 8. Robot orientation accuracy(validation,posesetQ$_2$).

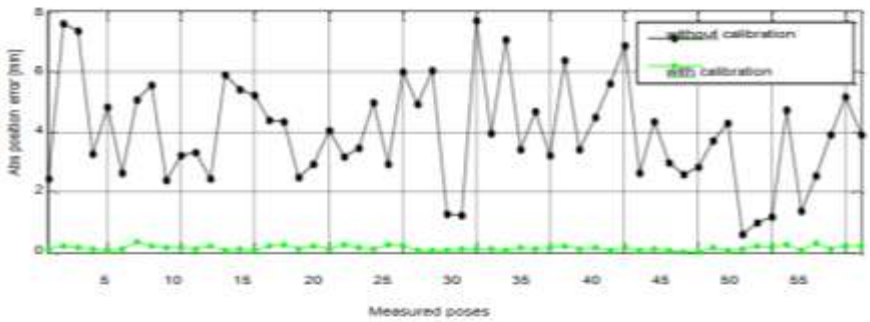

Figure9. Robot'sabsolute position accuracy (validation, pose setQ_2).

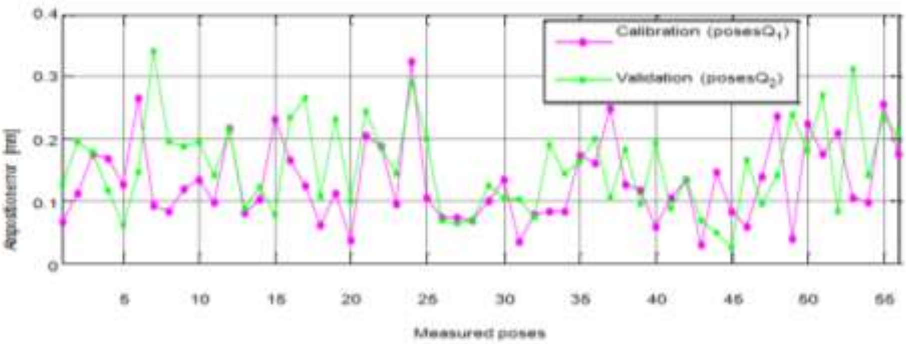

Figure10 . Absolute position accuracy at calibration posesQ_1 and validation poses Q_2

CONCLUSION

This paper proposes a new method for the full pose measurement of an end-effector for robot kinematic calibration. Full pose measurements could be obtained by analyzing the features of a set of target points (designated on a robot end- effector) on an arc of a circle, such as an orthogonal vector of a rotation plane and a rotation center. These points are measured by using external point sensing devices. This method benefits from the accuracy of available point measurement devices, such as Laser Tracker. The measurement procedure is simple, fast, easy to set up, and can be automated. It also does not use any special apparatus with an arrangement of intermediate measured points; therefore, no additional manufacturing costs or pre-calibration steps are required.

REFERENCES

1. Hutchinson,S.;Hager,G.D.;Corke,P.I.Atutorialonvisualservocontrol.IEEETrans.Robot.Auto. 1996, 12, 651–670.
2. Zhang,Z.;Luong,Q.-T.;Faugeras,O.Motionofanun-calibratedstereorig:Self-calibrationandmetric reconstruction.
3. IEEE Trans. Robot. Auto.1996, 12, 103–113.
4. Grosso,E.;Metta,G.;Oddera,A.;Sandini,G.Robustvisualservoingin3-Dreachingtasks. IEEETrans. Robot. Auto. 1996, 12, 732–742.
5. Dudek,G.;Jenkin,M.;Milios,E.;Wilkes,D.Usingmultiplemarkersingraphexploration. Proc.SPIE 1989, 1195, 77–87.
6. Kemmotsu, K.; Kanade, T. Sensor Placement Design for Object Pose Determination with ThreeLight-Stripe Range Finders. In Proceedings of 1994 IEEE International Conference on RoboticsandAutomation, San Diego, CA, USA, 8–13May 1994; Volume 2, pp. 1357–1364.
7. Khadraoui, D.; Motyl, G.; Martinet, P.; Gallice, J.; Chaumette, F. Visual servoing in roboticsscheme using a camera/laser-stripesensor.
8. IEEETrans. Robot. Auto. 1996,12, 743–750.
9. Hager, G. D. ;Chang, W.-C .; Morse, A. S. Robot hand-eye co ordination based on stereovision.
10. IEEE Cont. Syst. 1995,15, 30–39.
11. Hashimoto, K.; Ebine, T.; Kimura, H. Visual servoing with hand-eye manipulator-optimal control approach.
12. IEEE Trans. Robot. Auto.1996, 12,766–774.
13. Faibish,S.;Bacakoglu,H.;Goldenberg,A.A.AnHandEyeSystemforAutomatedPaperRecycling. In Proceedings of 1997 IEEE International Conference on Robotics and Automation, Albuquerque,NM, USA, 20–25 April1997; pp. 9–14.
14. Omodei, A.; Legnani, G.; Adamini, R. Three methodologies for the calibration of industrial manipulators: Experimental resultson aSCARArobot.J. Robot. Syst.2000, 17,291–307.
15. Everett, L.J. Completing the forward kinematic calibration of open loop manipulators when single point position sensors are used. J. Robot. Syst. 1989, 6, 19–33.
16. Morris, R. D. Full-pose calibration of a robot manipulator using a coordinate measuring machine.

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