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Modeling of Inverse Kinematic Analysis of Open-Source Medical Assist Robot Arm by Python

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Abstract

Today, the epidemic diseases such as COVID-19 spreads very fast in the globalizing world and lethal effects on human health have had a noticeable effect on the health sector. For this situations, various disciplines have had different studies to minimize the effects of the epidemic. In such cases, it is a separate requirement that the use of the opportunities brought by technology. In this study, the kinematic analysis of the open-source robot arm was especially examined in terms of reducing the workload of individuals working in the healthcare sector. The open-source robot arm is articulated and has 5 degrees of freedom. The kinematic analysis is very important for determination of the working space of the robotic systems. The inverse kinematic analysis was done with Python programming language and the control module was developed to check the analysis. The control module shows the angle values depending on the joints of the robot arm. It is also shown the Px, Py, and Pz positions obtained depending on the position of the end effector in 3D space. On the other hand, Euler angle values are also specified, which are based on the position of the last position taken by the joints of the robot arm in the 3D space. In the study, the geometric approach method was used that is still popular in the inverse kinematic analysis. It is hoped that this study will inspire the development and use of professional and industrial kinds of the open-source robot arm.

Keywords: Open-Source Robot Arm, Inverse Kinematic Analysis, Python

1. Introduction

Robot technology is an advanced technology innovation that requires a multidisciplinary area of research. In robot technology, numerous disciplines such as computer science, information and sensor technology, mechanisms, control theory and artificial intelligence need to cooperate. The prevalence of robotic arms, which are frequently used in industrial applications, is expanding day by day. On the other hand, the sophisticated robotic arms are both expensive and hard to maintain systems. The fact that epidemic diseases such as COVID-19, which today threatens human health, is a global treat, has revealed the importance of the healthcare staff especially in hospital in pandemic situations. In this study, open-source humanoid robot arms were emphasized to reduce the workload of healthcare professionals. Any contribution that can be made in pandemic situations where human health is a need has significance. However, it is obvious that the use of advanced scale robotic systems in hospitals would pose both maintenance and expense burdens. Considering these situations, it will provide a significant cost gain that the production of open-source robotic arms on a professional scale printed from 3D printers and the development of control software as an open-source compared to their professional scale equivalent.

On the other hand, it is of special importance that spare parts and maintenance are also easily provided. Determining of the working space of the robot arm is one of the most important issues in the robotic systems. This determination of workspace is possible by kinematic analysis. The working space is expressed by the point coordinate that end effector on the robot arm will form in three-dimensional space. There are some solutions methods for determination of the location of robot arm in the working space. Those are listed mainly as graphical method, analytical method and numerical method. The graphical method and analytical method are limited by the number of joints and inadequate in defining some robot arms, although, both the amount of calculation and the reliability in the numerical method cannot be guaranteed for some cases [1, 2]. Two different space is used in kinematic analysis, Cartesian space and Quaternion space. The transformation between two Cartesian coordinate systems can be reduced to one turn and one translation. It is among used the methodologies to represent rotation that Cayley-Klein parameters, Gibbs vector, Euler angles, and orthonormal matrices, while in robotics, homogeneous transformations based on 4x4 real matrices are predominantly used [3]. In the study, it was examined the kinematic analysis of open-source professional 5 degree of freedom robotic arm obtained from 3D printer by Denavit-Hartenberg (D-H) method [4].

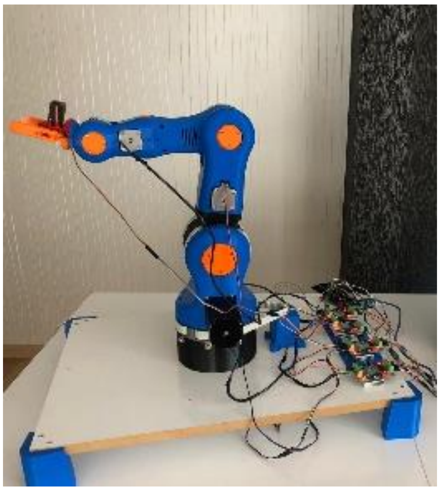

Figure 1. Medical Assist Robot arm printed from the 3D printer

Python programming language was used to determine the analysis of the workspace, and the position of the robot arm in the workspace was analyzed by the D-H method. It was examined the inverse kinematic analysis after determination of the working space of robot arm. kinematic analysis of the medical assist robot arm is open-source software format. Open-source medical assist robot arm is suitable for development (figure 1). The robot arm is also an articulated kind. Kinematic analysis is extremely important in robotic systems, in other words, it is equivalent to controlling robotic systems. In particular, inverse kinematic modelling continues to pose one of the major problems in today's robot research. On the other hand, the most popular method for controlling robotic arms is as yet dependent on manually designed scanning tables [5 – 8]. The D-H method is used to determine working space of robot arm and its position to control. The key to the D-H method is to demonstrate the relationship of the coordinate system of all joints. In the scope of the method, a series of D-H parameters are created.

2. Robot Arm Kinematic

In robotic systems, kinematic analysis is divided into two parts, forward and inverse kinematics. While the inverse kinematic analysis examined, the complexity of the equations makes the solutions difficult, however this is not the case in forward kinematic analysis. The obvious reason for the complexity is not particularly linear. Although nonlinear equations cannot be combined, there are no one-to-one solutions. While nonlinear equations cannot combine, moreover, the do not have unique solutions. There are numerous studies in this searching area, while in certain studies the geometric approach is used for inverse kinematic analysis solutions [9], while in some other studies double quaternion is used [10]. Particularly in many recent studies, it is seen that artificial intelligence (AI) methods are used in inverse kinematic solutions of robotic systems [11 – 13]. Among the prominent studies, while the position/force values are used for the control of the dual robot system [14], the robot arm was controlled by calculating of the position/force values required for the B-Hand robots with 4 degrees of freedom [15].

2.1. Inverse Kinematic Analysis

Different approaches have been adopted for kinematic analysis of robotic systems and especially for inverse kinematic solutions. In the study [16], closed form solution and zero moment point approach were used in the robotic system with 18 DoF. In another study, optimal path in Cartesian space was performed using the particle swarm optimization (PSO) algorithm for inverse kinematic of the robot arm with two degrees of freedom [17]. Inverse kinematic analysis of the robot arm with two degrees of freedom was developed using the genetic algorithm approach by Chaitanyaa et al. [18]. Jones and Walker developed inverse kinematic analysis for the continuum robots within the structure of the modular approach [19]. Radavelli et al. performed the kinematic analysis of robotic systems by comparing DH convention and Dual Quarternion approaches [20].
In a study conducted in 2015, screw theory was used in the inverse kinematic analysis process [21]. In another conducted study, the metaheuristic methods were used to determine the working space of robots [22]. In the study [23], analytical inverse kinematic solution was done with data obtained from D-H tables. At the point when the literature is examined, especially, that are developed numerous different inverse kinematic analysis solutions in robotic systems. The studies of inverse kinematic solutions are limited compared to geometric approaches. It means that the geometric approach is still prominent in inverse kinematic solutions. The inverse kinematic analysis is a basic assignment for the operation and structure of robotic systems. Analysis of this critical problem continues to pose serious problems in the robotic systems. It is basic to make the most inverse kinematic calculations for complete control of the robotic system. In particular, serious problems are posed to determine the position of the robot and the calculation of all joint angles

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corresponding to the position [24]. Although there are numerous packages available for numerical inverse kinematics, an initial value is required to find just one of the multiple solutions. Besides, normal requirements, for instance, it must be overcome that dependency and convergence of individual initial value configurations [25, 26].

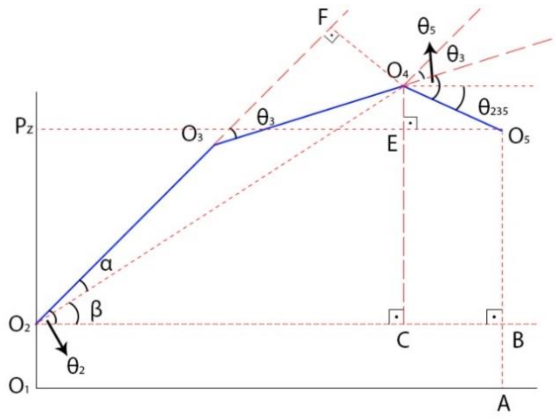

Figure 2. Solution of the inverse kinematic analysis of robot arm by geometric approach method

Briefly, inverse kinematic analysis in robotic systems is called the analysis of the end effector and how many different configurations can be performed. In other words, if n, o, a, and p variables and geometric variables are known, joint variables can be resolved in kinematic solutions θ_i (i = 1, 2, …, 6) [27]. The equation required for the solution of inverse kinematic is as follows. Geometric method is used for the inverse kinematic solution of the medical assist robot arm (figure 2).

3. Control Module of Robot Arm

In the study, it was examined the inverse kinematic analysis of the medical assist robot arm with Python programming language. The graphical user interface (GUI) was developed via Python to control inverse kinematic analysis. The model GUI was designed as shown in figure 3 below, the controlled system was simulated too. The robot arm is shown in figure 1 and it has 5 active joints. 3rd and 4th joints are connected to each other in form of twisting joints. The controlled functions via the GUI are as follows;

- Controlling the simulation process
- Monitoring of joint angle information
- Obtaining exposure information of the manipulator

In this study, an open-source robot arm was printed on the 3D printer and it was 5 DoF features that aims to help hospital staff. Additionally, the kinematic analysis was performed to control robot arm. Inverse kinematic analysis of the robot was performed via the GUI. In the solution of the kinematic equation, it was used homogeneous transformation theory. The GUI interface was prepared with Python programming language. The biggest advantage of the robot arm prepared within the scope of the study is that it has 5 DoF degree of freedom at a professional usage and its production cost is low. In the next phase of the study, which is aimed to reduce workload of healthcare staff as much as possible, robotic arm will be designed based artificial intelligence applications that will be created by parallel operation.

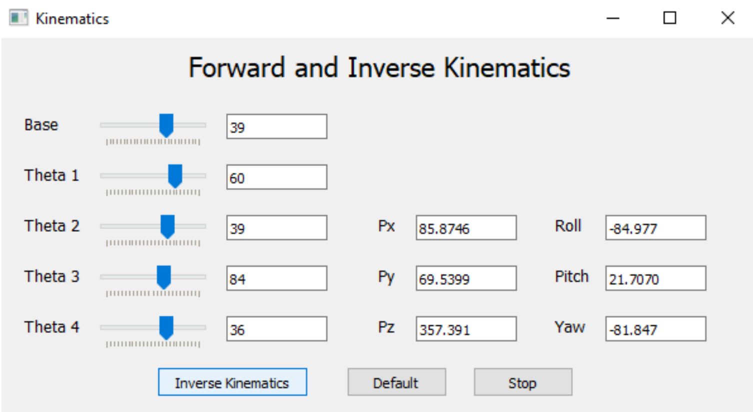

Figure 3. Control module prepared with Python programming language

In the prepared the GUI interface, in the inverse kinematic analysis, it is specified the position of Px, Py, and Pz depending on 5 angles obtained from the position of the end-effector. While the position of the end-effector is determined in the working space, Euler angles are also calculated and shown in the interface.

4. Conclusions and Recommendations

In this study, it was performed the inverse kinematic analysis of open-source robot arm with 5 DoF. In the inverse kinematic analysis process, it was determined conceivable inverse movement of the robot arm in the working space. During the analysis phase, the D-H parameter table was created and an analysis was made based on the homogeneous transformation theory. The GUI interface was created via Python for analysis. It is hoped that this study will inspire the development of open-source robotic systems especially professional kinds robotic arm, and the development of kinematic analysis.

Author's Contributions

Mehmet Gül: Drafted and wrote the manuscript, performed the experiment and result analysis.

Ethics

There are no ethical issues after the publication of this manuscript.

References

1. Haibo, T, Hongwei, M, Juan, W. 2013. Workspace and Structural Parameters Analysis for Manipulator of Serial Robot Manipulator workspace analysis using the Monte Carlo method, J. Transactions of the Chinese Society for Agricultural Machinery, 44 p. 196-201.

2. Ming, Z, Qingzhong, H. 2013. The Workspace Analysis of the Articulated Palletizing Robot, J. Modular Machine Tool & Automatic Manufacturing Technique, 7 p. 68-74.

3. Funda, J, Taylor, RH, Paul, RP. 1990. On homogeneous transforms, quaternions, and computational efficiency, IEEE Trans. Robot. Automation 6, pages 382–388.

4. Klafter, RD, Chmielewski TA, Negin. M. 1989. Robotic Engineering: An Integrated Approach. Prentice Hall.

5. Mittal, RK, Nagrath, J. 2005. Robotics and Control, Tata McGraw-Hill.

6. McKerrow, PJ. 1991. Introduction to Robotics. Addison-Wesley.

7. Niku, SB. 2001. Introduction to Robotics: Analysis, Systems, Applications. Prentice Hall.

8. Denavit, J, Hartenberg, RS. 1955. A kinematic Notation for Lower- Pair Mechanism Based on Matrices. ASME Journal of Applied Mechanics, 215-221.

9. Liu, Y, Wang, D, Sun, J, et atl. 2015. Geometric approach for inverse kinematics analysis of 6-dof serial robot, IEEE International Conference on Information and Automation, pages 852-855

10. Qiao, S, Liao, Q, Wei, S, Su, H. 2010. Inverse kinematic analysis of the general 6R serial manipulators based on double quaternions, Mechanism and Machine Theory 45, 193-199.

11. Almusawi, ARJ, Dülger, LC, Kapucu, S. 2016. A new artificial neural network approach in solving inverse kinematics of robotic arm (denso vp6242), Computational Intelligence and Neuroscience

12. Köker, R. 2013. A genetic algorithm approach to a neural-network-based inverse kinematics solution of robotic manipulators based on error minimization, Information Sciences 222, 528-543.

13. Duka, AV. 2014. Neural network based inverse kinematics solution for trajectory tracking of a robotic arm, Procedia Technology 12, 20-27.

14. Uchiyama, M, Iwasawa, N, Hakomori, K. 1987. Hybrid positon/force control for coordination of two-arm robot. in Proceedings of the IEEE International Conference on Robotics and Automation, pp. 1242–1247.

15. Kopf, CD, Yabuta, T. 1988. Experimental comparison of master/slave and hybrid two arm position/force control. in Proceedings of the IEEE International Conference on Robotics and Automation, vol. 3, pp. 1633–1637.

16. Mandava, RK, Vundavilli, PR. 2016. Forward and inverse kinematic based full body gait generation of biped robot. Proceedings of the International Conference on Electrical, Electronics and Optimization Techniques, Mar 3-5, IEEE Xplore Press, Chennai, India, pp: 3301-3305. DOI: 10.1109/ICEEOT.2016.7755317

17. Sadiq, AT, Raheem FA, Abbas, NA. 2017. Optimal trajectory planning of 2-DOF robot arm using the integration of PSO based on D* algorithm and cubic polynomial equation. Proceedings of the 1st International Conference for Engineering Researches, (CER' 17), Middle Technical University, Baghdad-Iraq, pp: 458-467.

18. Chaitanyaa, G, Reddy, S. 2016. Genetic algorithm based optimization of a two Link planar robot manipulator. Int. J. Lean Think., 7: 1-3.

19. Jones, BA, Walker, ID. 2006. Kinematics for multisection continuum robots. IEEE Trans. Robot., 22: 43-55. DOI: 10.1109/TRO.2005.861458

20. Radavelli, L, Simoni, R, De Pieri E, Martins, D. 2012. A comparative study of the kinematics of robots manipulators by Denavit-Hartenberg and dual quaternion. Mecánica Comput. Multi-Body Syst., 31: 2833-48

21. Chen, Q, Zhu S, Zhang, X. 2015. Improved inverse kinematics algorithm using screw theory for a sixDOF robot manipulator. Int. J. Adv. Robotic Syst., 12: 140-140. DOI: 10.5772/60834

22. Raheem, FA, Sadiq AT, Abbas, NAF. 2019. Robot arm free Cartesian space analysis for heuristic path planning enhancement. Int. J. Mech. Mechatron. Eng., 19: 29-42.

23. Sun, JD, Cao, GZ, Li, WB, Liang, YX, Huang, SD, 2017. Analytical inverse kinematic solution using the D-H method for a 6-DOF robot. Proceedings of the 14th International Conference on Ubiquitous Robots and Ambient Intelligence, Jun. 28-Jul. 1, IEEE Xplore Press, Jeju, South Korea, pp: 714-716. DOI: 10.1109/URAI.2017.7992807

24. Xiao WL, Henning S, Torsten L, et al. 2011. Closed-form inverse kinematics of 6R milling robot with singularity avoidance. Prod Eng Devel 5:103–110

25. Corke, PI. 1996. A robotics toolbox for matlab. IEEE Robotics Automation Magazine, vol. 3, no. 1, pp. 24–32

26. Kelmar L, Khosla, PK. 1990. Automatic generation of forward and inverse kinematics for a reconfigurable modular manipulator system," Journal of Robotic Systems, vol. 7, no. 4, pp. 599–619 [Online]. Available: http://dx.doi.org/10.1002/rob.4620070406

27. Wu Y, Cheng LH, Fan GF, et al. 2014. Inverse kinematics solution and optimization of 6-DOF handling robot. Appl Mech Mater 635–637:1355–1359