

Performance Evaluation of a Forward Kinematic Hand Model

Jabar Salman

Alaa Hussien Ali

Thamir Rashed Saeed

University of Technology-Dept. of Electrical Eng.-Iraqjabbars174@yahoo.comalaa_eng1970@yahoo.comthamir_rashed@yahoo.com

Abstract

Many fields of life has been used a robot, the specialty of the robot is coming from its accuracy. Therefore, this paper has been presented the evaluation of the robots arm performance on the one hand of consuming time and required end-position. Where, The time consuming required for the hand to reach to the desired position is taken 1.4614×10^{-4} sec., while for finger adding to the arm is taken 0.00019sec.. Also, the error position has been evaluated with different NSPR (0.1-1), where the error amount are 0-12mm.

Keywords: Forward Kinematic, Hand Model, error of robotic arm

الخلاصة

العديد من مجالات الحياة تستخدم الانسان الآلي، وخاصة الانسان الآلي متاتية من دقته. لذلك، تقدم هذه الورقة تقييم أداء ذراع الانسان وذلك من خلال الوقت المستغرق للوصول الى النقطة النهائية المطلوبة، وموقع نقطة الوصل المطلوبة ليد واحدة. حيث ان الزمن المستغرق للذراع للوصول الى الموقع المطلوب هو تقريبا $(1.4614 \times 10^{-4} \text{sec})$ ، بينما للأصبع مضافا لليد هو تقريبا (0.00019sec) ، كذلك تم حساب نسبة الخطأ في الموقع او في عملية الوصول الى الموقع النهائي مع مختلف نسب الخطأ (0.1-1NSRP)، وجد ان نسبة الخطأ هي (0-12mm).
الكلمات المفتاحية: كينماتيك الامامي، نموذج اليد، خطأ ذراع الانسان الآلي.

Introduction:

Robotics is a very vast field and expanded daily, which it is make robotic lives (Chinello, 2010). In this context, one of the important application is for assist the people with special needs as a robotic arm. While, There are a lot of robotic arms simulation that is controlled using human gestures or voice (Salem,2014). In that applications, the interference and control of the arm are represented the important joint in the robotic arm. Therefore, (Shivoni,2015; Kaura,2013) have been concentrated in the interference demand, while(Feldman,2010;Lauren,2001) have been concentrated on the control issue. Where(Shivoni,2015) is focused on interfacing the hardware with software in the arm implementation. While (Kaura,2013) was used friendly interfaces, where the user can give his commands to a wireless robot using gestures action by using image processing. In this context, the robotic arm in (Feldman,2010)has been controlled by using the combination sensors of electromyography and voice. Also,(Lauren,2001) is based his prototype of a tactile sensing platform by using a simple control of a planar 2- Degree of Freedom (DOF) robotic finger inspired by anatomic consistency, self-containment, and adaptability.

The main challenge in the robotic operation is determined the place to be accessed. Where the robotic usually needed steer to Things from one place to other.

This paper has been concerned with the physical part of hand and fingers, where, a mathematical models has been analyzed. Then, the error caused by unsuitable finger parts length and instrumentation noise which effects on the finger end point desired steered position has been evaluated.

Mathematical analysis

The joint angles and positions vectors of the robot are represented the main parts of the robot arm. These vectors have been described by utilizing the kinematics relations of the robot controller which depicts the connection between the movement of the joints of the controller and the subsequent movement of the unbending bodies. The kinematic analysis is the describe of the relationships between the positions,

velocities, and accelerations of the links of a manipulator. There are two types of kinematics representation; Forward (direct) Kinematics (FK) and inverse kinematics. In the forward kinematics, the position of required end point in the robot work field has been calculated based on the link length and joint angle (Feldman,2010). In the inverse kinematics, the length of each link and position of the point in work field is given, while, the angle of each joint has been calculated (Argell,2009; Yavuz,2009). In this context, the inverse problem solution is in contrast of the forward and not have a unique solution(Chinello,2010).

In this context, the arm contains two parts the hand and the fingers. Where the goal of the arm movement is to reach to the desired position. The arm movement has been taken two stages to reach the required position. The first stage is by the hand, which reach to the certain point and then fingers complement to get to the desired position. Therefore, this position can be calculated by calculating the hand and finger position.

In this research, the positions of both hand and fingers have been calculated. Therefore, Forward Kinematic has been used.

Hand movement: (Bundhoo,2005)

To calculate the point which the hand can reach to it, for steering the finger to reach the desired position, consider the planar manipulator as;

Let $E = (x, y, \varphi)$

Where;

E - the position and orientation of the end-effector.

The forward kinematics of the mechanism can be derived using the product of exponentials formula, but are more easily derived using plane geometry as shown in figure (1) are;;

$$\left. \begin{aligned} x &= l_1 \cos \theta_1 + l_2 \cos(\theta_1 + \theta_2) + l_3 \cos(\theta_1 + \theta_2 + \theta_3) \\ y &= l_1 \sin \theta_1 + l_2 \sin(\theta_1 + \theta_2) + l_3 \sin(\theta_1 + \theta_2 + \theta_3) \\ \varphi &= \theta_1 + \theta_2 + \theta_3 \end{aligned} \right\} 1$$

where;

$l_1, l_2,$ and l_3 - the link lengths for a 3R planar manipulator,

$\theta_1, \theta_2,$ and θ_3 - the link angles of the manipulator,

φ - the end-effector orientation.

To calculate the reachable workspace, firstly, ignoring the end-effector orientation, then take θ_1 and θ_2 as fixed values. Then, the reachable points

becomes a circle of radius l_3 formed by sweeping θ_3 . Now let θ_2 (0-360°) to get an annulus with radius $l_2 - l_3$ and outer radius $l_2 + l_3$ centered at the end of the first link. Finally, generate the reachable workspace by sweeping the annulus through all values of θ_1 , to give the reachable workspace.

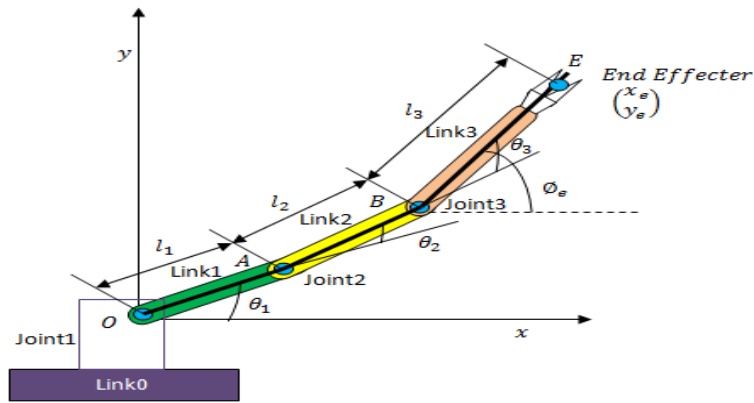


Fig. 1. The joint variables of a 3R planar manipulator.

From figures (1), the hand with three axis movement that needs three dimension equations have been needed to calculate the end fingers position as follows:

$$\begin{bmatrix} E_x \\ E_y \\ E_z \end{bmatrix} = \begin{bmatrix} C_1(a_2C_2 + a_3C_{23} + d_4S_{23}) - d_2S_1 \\ S_1(a_2C_2 + a_3C_{23} + d_4S_{23}) + d_2C_1 \\ d_4C_{23} - a_3S_{23} - a_2S_2 \end{bmatrix} \dots\dots\dots 2$$

Where;

$$C_i = \cos\theta_i ; S_i = \sin\theta_i ; C_{ij} = \cos(\theta_i + \theta_j) ; S_{ij} = \sin(\theta_i + \theta_j)$$

i, j - are the index for each angle,

a_i - is the approach vector of the hand, it is pointing in the direction normal to the palm of the hand, and

S_i - is the sliding vector of the hand, it is pointing in the direction of the finger motion as the gripper opens and closes

The production of a multi-fingered human automated hand is a test that requests creative incorporation of mechanical, hardware, control and inserted programming plans. Where the finger has three diverse phalanxes: Distal Phalanxes, Middle and Proximal. These phalanxes are isolated by joints, these joints are called the Interphalangeal. The Interphalangeal joints work like pivots for twisting and rectifying the thumb and the fingers. The Interphalangeal joint close to the palm is known as the Metacarpals joint. Then, to the Metacarpals joint is the Proximal Interphalangeal joint which is in the middle of the Proximal and Middle Phalanx of a finger. The joint toward the finish of the finger is known as Distal Interphalangeal joint . Both Proximal Interphalangeal and Distal Interphalangeal joints have one DOF attributable to spinning movement.

Thumb is a complex bodily formation among the fingers and just as Interphalangeal joint between the phalanxes. With the exception of the thumb, the other fingers have comparable structures in regards to kinematics and elements highlights (Zaidy,2013).

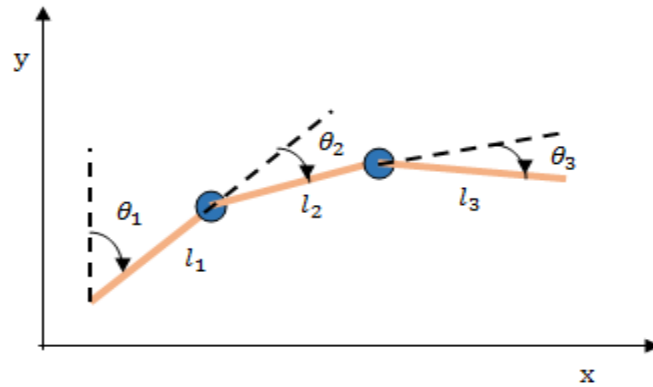


Fig. 2. Angles flexion for finger

Based on the Fig. 2, the Lagrangian method was used to derive the dynamics, according to the forward kinematics solutions [Zaidy2013] as;

$$\left. \begin{aligned} Ex &= l_3 s_{234} + c_1(l_2 c_{23} + l_1 c_2) \\ Ey &= l_3 s_1 s_{23} + s_1(l_2 c_{23} + l_1 c_2) \\ Ez &= l_3 c_{234} + l_3 s_{23} + l_1 s_2 \end{aligned} \right\} \dots\dots\dots 3$$

Dimensions of the hand fingers differ from one human to the other according to their length and others factors. Also, for robotic hand and their fingers dimensions differs from one to another, based on the design, the application used for, and the materials that it builds from (Murray,1994 ; Zhe Xu,2012).

Error sources

Two sources of error have been effected on the desired position which the arm and finger want to reach to it. The first one is caused by the uncorrected finger length, while the other is caused by the interference and instrumentation error.

The result

So, the fingers length differs as shown in the table (1)(Murray,1994; Zhe Xu,2012), which represent the first error types, while the error has occurred when the unsuitable length has been used as shown in that table.

Table (1) Percentage error of finger length from min. to Max. finger length

Finger Part	Average finger length mm	Min length mm	Max length mm	Error%
<i>l1</i>	25	17.3	53.4	44.5 - 53
<i>l2</i>	27	21.6	32	25 - 15
<i>l3</i>	35	32.8	23.7	6.7 - 47
Total	87	72	109.1	20.8 - 25

The end position has been found for hand and fingers, then the error position which is caused by additive noise has been evaluated, where, it represents the second type of errors.

Where, figure (3) is shown one hand position $E(x,y,z)$ form one angle without error, while figure (4), shows the position of the hand $E(x,y,z)$, for multi-angle which are produced many positions without error also.

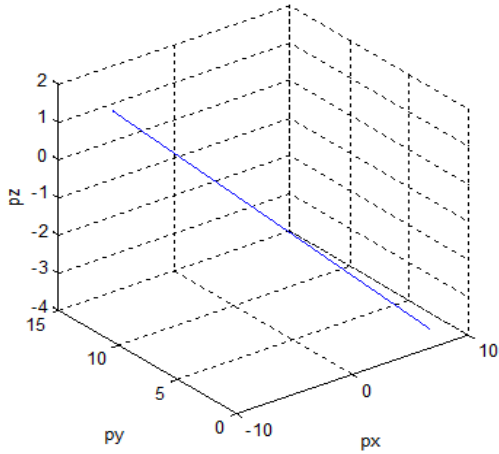


Fig.3. Hand positions, for one move

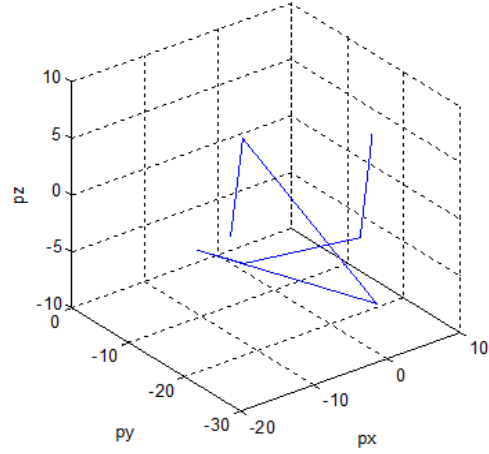


Fig. 4. hand positions, for multi-angles

The time consumed to reach to the required position for the arm is 1.4614×10^{-4} sec., while for the single finger is 1.9×10^{-4} sec. Therefore, the effect of the error in the robotics operation has been evaluated by adding the additive white Gaussian noise to the input parameters to express its effect on the output positions. Figure (5) represents the angles against required positions without errors for three axes.

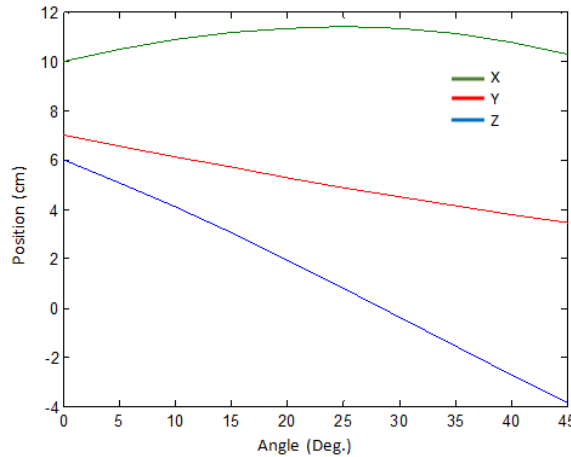


Fig.5. The angles against required positions without errors.

While the performance of the arm system with adding a white Gaussian noise has been evaluated. In this context, the performance deviation from the required position has been declared for NSPR is 0.1, the amount of error is 1.5-9 as shown in figure (6).



Fig.6. The amount of error for three axes with NSPR=0.1.

While the amount of error is 2.5-6 with NSPR =0.5 as shown in figure (7)

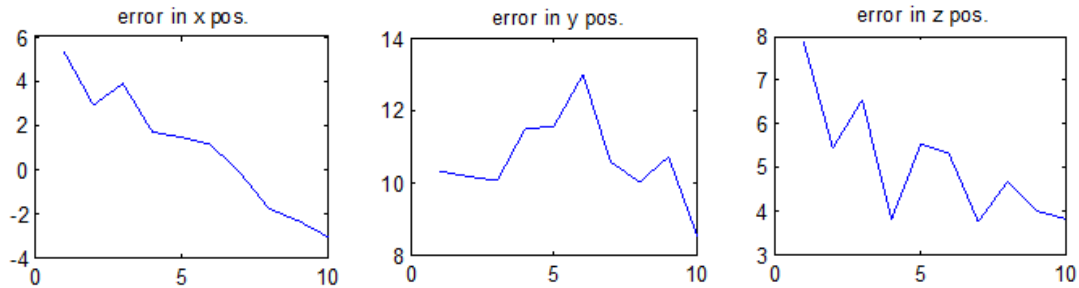


Fig.7. The amount of error for three axis with NSPR =0.5.

In general, the amount of error with NSPR is shown in figure (8)

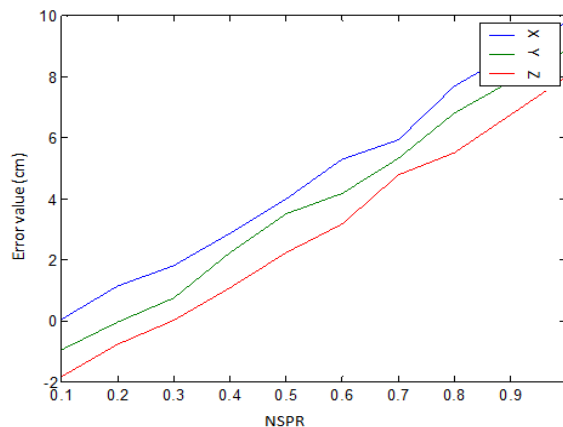


Fig. 8. The amount of error with NSPR

Conclusions

The performance of the robotic arm with five fingers has been evaluated for the selected mathematical modules. The evaluation has been made for two important parameters; the required position and the consuming time. The time consuming required for the hand to reach the to the desired position is taken 1.4614×10^{-4} sec., while for any finger added to the arm is taken 0.00019 sec.. Also, the error position has been evaluated with different NSPR (0.1-1), where the error amount are 0-12mm.

References:

- Aaron Feldman, Chance Martin, Shang-Li Wu, Sami Malek, Edward A. Lee, Alberto Sangiovanni-Vincentelli, Antonio Iannopolo, Ben Zhang, John Finn 2010, "Robotic Hand", University of California, Berkeley.
- Abdul Haseeb Zaidy, Mohd. Rehan, Abdul Quadir, Mohd. Parvez, March-April. 2013 " Dynamic Model Of Anthropomorphic Robotics Finger Mechanisms." ,*India International Journal of Modern Engineering Research (IJMER)* www.ijmer.com Vol.3, Issue.2, pp-1061-1065 ISSN: 2249-6645.
- Brenna D. Argall, March 2009 "Learning Mobile Robot Motion Control From Demonstration And Corrective Feedback", Thesis University of Southern California.
- Farhan A. Salem, 2014 "Modeling, Simulation And Control Issues For A Robot Arm; Education And Research", *I.J. Intelligent Systems And Applications*, , 04, Pag. 26-39.
- Francesco Chinello, Stefano Scheggi, Fabio Morbidi, Domenico Prattichizzo the September 20, 2010, Kuka Control Toolbox : Motion Control Of Kuka Robot Manipulators With Matlab, *Ieee Robotics And Automation Magazine*, Submitted For Publication As A Regular Paper.

- Harish Kumar Kaura, Vipul Honrao, Sayali Patil, Pravish Shetty,2013,"Gesture Controlled Robot using Image Processing",Department of Computer Engineering Fr. C. Rodrigues Institute of Technology, Vashi Navi Mumbai, India (IJARAI) International Journal of Advanced Research in Artificial Intelligence, Vol. 2, No. 5.
- Jessica Lauren , May 2001 "Design and Control of an Anthropomorphic Robotic Finger with Multi-point Tactile Sensation", massachusetts institute of technology — artificial intelligence laboratory, MSc thesis.
- Richard M. Murray, Zexiang Li and S. Shankar Sastry,1994 "A Mathematical Introduction to Robotic Manipulation" , CRC Press, electronic edition is available from <http://www.cds.caltech.edu/~murray/mlswiki>. Hardcover editions may be purchased from CRC Press, <http://www.crcpress.com/product/isbn/9780849379819>.
- Shivani, Shagun Gaur,Paresh Khaneja,Rashmi Sharma,Simranpreet Kaur,Mehakpreet Kaur,2015(Efficient Approach for Designing Gesture Controlled Robotic Arm). Department of ECE Chitkara University, Chandigarh, India, International Journal of Control and Automation Vol. 8, No. 6, pp. 55-64.
- Sırma C. Yavuz ,2009 "Kinematic Analysis For Robot Arm" ,Yildiz Technical University, Electrical And Electronics Faculty, Department Of Computer Engineering, Project Group 04011503 COŞKUN YETİM, İstanbul.
- Vishalini Bundhoo and Edward J. Park, 2005 "Design of an Artificial Muscle Actuated Finger towards Biomimetic Prosthetic Hands", IEEE Conference Publications, ICAR '05. Proceedings., 12th International Conference on Advanced Robotics, Pages: 368 - 375.
- Zhe Xu, Vikash Kumar and Emanuel Todorov, October 15 - 17, 2013 "A Low-cost and Modular, 20-DOF, Anthropomorphic Robotic Hand: Design, Actuation and Modeling.", 13th IEEE-RAS International Conference on Humanoid Robots (Humanoids).. Atlanta, GA.
- Zhe Xu, Vikash Kumar, Yoky Matsuoka and Emanuel Todorov, June 24-27, 2012 "Design of an Anthropomorphic Robotic Finger, System with Biomimetic Artificial Joints", Fourth IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics Roma, Italy.