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THEORETICAL INVESTIGATION ON KINEMATIC MODELLING OF A MULTI FINGERED ROBOTIC HAND

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ABSTRACT

To accommodate the multi task accomplishments like stable grasping and fine manipulation in different fields such as rehabilitation, service robots, humanoid robots and industrial applications, attention has been pointed out on multi fingered robotic hand. The key step in this context is the mathematical modelling of the multi fingered robotic hand. As the behaviour of robots is very important for different applications, the kinematic modelling is essential for critical analysis. Based on this, present article encompasses the mathematical modelling of a multi fingered robotic hand synonymous to the biological human hand. Each link of the modelled robotic hand interconnected through distal interphalanngeal joint (DIP), proximal interphalanngeal joint (PIP), metacarpo phalangeal joint (MCP) and carpometacarpal joint (CMC) respectively. In the proposed model the modelling is carried out using Euler-langrangean formulation and Denavit Hartenberg algorithm.

KEYWORD: Multi Fingered Robotic Hand, Euler-Langrangean Formulation And Denavit Hartenberg Algorithm

The most taught and multifaceted outer uttermost point on human body is human hand. The hand is a champion among the most structures and load bearing part which goes about as material recognizing and likewise physical work contraptions to human. Human hands can overwhelmingly conform to objects with subjective shape and size in the midst of understanding. David, 1995 has given a setup space depiction of the kinematics of the fingers notwithstanding question structure for multi fingered control. Emily, 2007 has construed kinematics and movement conditions in the arrangement of a human robotized hand for space operation. Parasuraman and Shiau, 2008 have construed kinematics and movement conditions for bio-mechanical examination of human joints. Parasuraman, 2008 has upgraded kinematics assurance for humanoid robot controllers to be used as a part of the generation MFRH using virtual reality toolbox. Valentin et. al., 2009 have given acceptance for bearing organizing of a robot controller. Kevin and Thurston, 1993 have derived kinematics examination of novel 6 DOF parallel controller. This kinematic examination is used for three elbow edges before enrolling the position and presentation of the top plate. Mina et. al., 2008 have used inverse kinematics to find the joint of the robot finger. In dynamical model, Yavin, 2009 has surmised the kinematic and component for three-associate controller. Aarts and Jonker, 2002 have upgraded component reenactment for the planar versatile association controller. Panagiotis and Kostas, 1999 have upgraded the kinematics and component to find the position and drive of the robot arm in application to teleportation and orthosis. Ronen et. al., 1999 have used kinematics and component conditions for the planary versatile induced parallel robot. Aaron has decided forward and in reverse kinematic for naturally impelled able robot hand. Ramasamy and Arshad, 2000 in like manner have decided the state of kinematic and component to the robot hand entertainment using 30 Studio Max and Maya 30. The preliminary results of the survey were presented in the ICORAFFS meeting methods [Jacobsen et. al., 1986].

A Human hand has 23 DOF that is given by 17 joints [Siciliano and Khatib, 2009]. If three dimensional improvements are considered, degrees of adaptability augmentation to 29 because of presentation and position assortment of the hand. The joint of a multi-fingered robot hand is showed up in Fig.1The phalanges are the little bones that constitute the skeleton of the fingers and thumb. The nearest phalange to the hand body is called proximal phalange and the one toward the complete of the each finger is called distalphalange. The joints of the finger, the distal interphalangeal (DIP) and proximal bury phalangeal (PIP) joints have 1 DOF having rotational improvement and metacarpophalangeal (MCP) joint has 2 DOF inferable from adduction-grabbing and rotational developments. In any case, the thumb, the other four fingers (list, focus, ring and little fingers) have near structure with respect to kinematics and components highlights. Thumb is the most complex physical structure among the hand fingers and not the same as the fingers in that contains only two phalanges and has 5 DOF.

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METHODOLOGY

The flowchart in Fig. 1 shows the methodology used in this study for the development of Multi Fingered Hand.

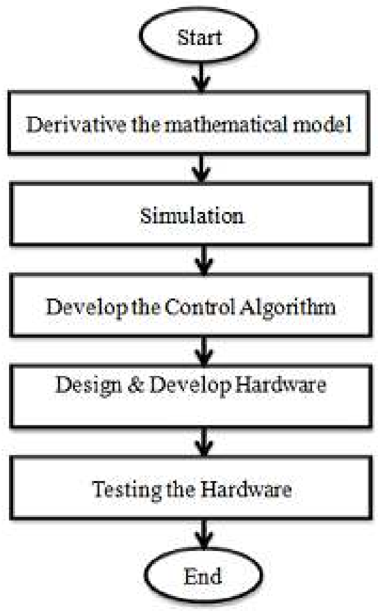
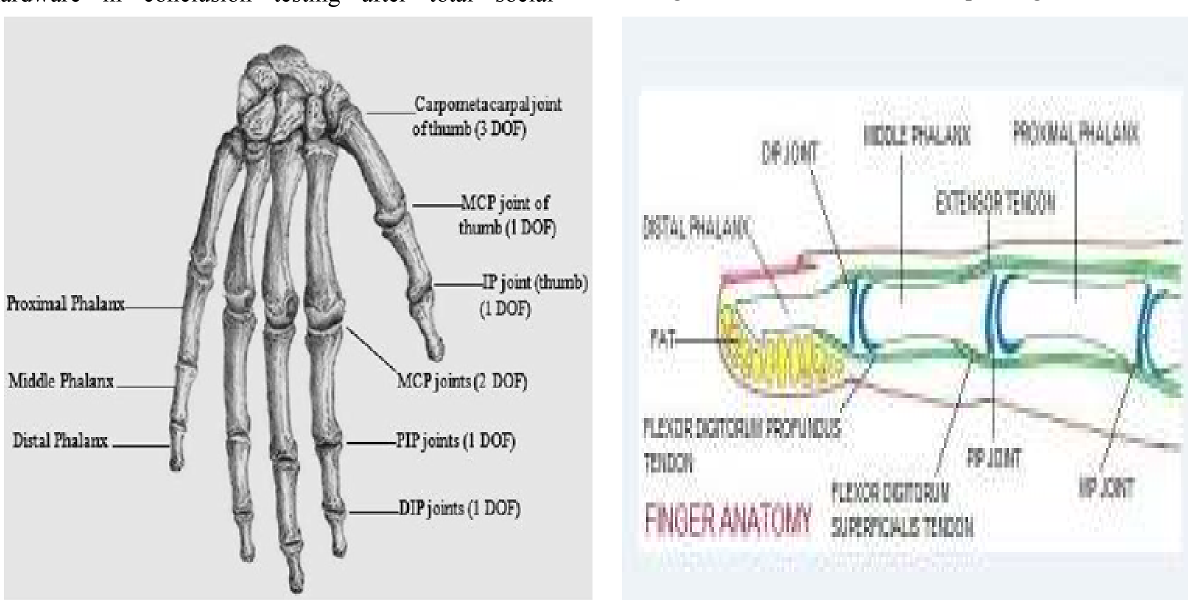


Figure 1: Flow chart of analysis

It incorporates the acceptance of numerical model, trailed by re-enactment using the decided logical model, headway of control count, layout and change of hardware in conclusion testing after total social gathering. This paper sets out the structure for the logical showing of kinematic and component conditions for the MFRH. The eventual outcomes of other audit would be disseminated as soon as possible. Logical exhibiting is basic in setting up the amusement of a MFRH. In this paper, the logical showing using the Denavit-Hartenburg (DH) count that gives a grid methodology to decide the kinematic respond in due order regarding MFRH is depicted. The kinematics condition is containing forward and inverts kinematics. The forward kinematic course of action of a MFRH can be used to choose the position and presentation of the robot turn in regard to the robot base encourages system. It is in like manner figures the joints of the robot hand. The joints of MFRH are referenced by the natural equivalent; each association interconnect at the metacarpophalangeal (MCP), proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints independently. The Jacobian and component in like manner are surmised to choose the torque and urge of the robot hand.

Human hand is a to a great degree clarified structure. The high helpfulness of the human hand relies on upon the higher degrees of adaptability. Human hand has 23 DOF that is given by 17 joints. If three dimensional improvements are contemplated, degrees of chance augmentation to 29 thus of presentation and position assortment of the hand. The joint of a multi-fingered robot hand is showed up in Fig. 2.



(a) (b)

Figure 2: (a) Anatomy of hand (b) finger

It incorporates the conclusion of logical model, trailed by entertainment using the gathered numerical model, change of control estimation, framework and headway of hardware ultimately testing after total party.

This paper sets out the structure for the logical showing of kinematic and component conditions for the MFRH. The eventual outcomes of other survey would be appropriated as soon as possible.

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MATHEMATICAL MODELLING

The proposed model of the multi finger automated hand is appeared in Fig. 3. The fingers are thought to be index, centre, ring, little finger and thumb.

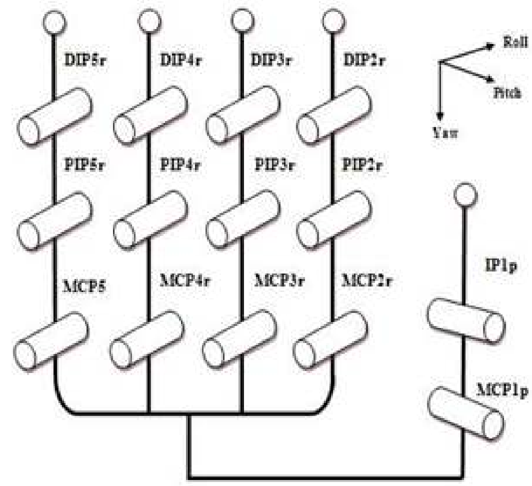

Figure 3: Model of a multi finger robotic hand

The finger has 3 dynamic joints. Plunge joint has association with PIP joint. The thumb is composed by having 2 dynamic joints. The joint of every connection of MFRH model is a casing to decide the kinematic induction. The casing are named by number as indicated by which they are

The z - hub of edge {i}, called {zi}, is correspondent with the joint i .The birthplace of edge {i} is found where the αI opposite meets the joint i hub. xi focuses along ai in the heading from joint i to joint i +1. Accepting that the edges have been joined to the connections as indicated by the D-H tradition, the accompanying meanings of the connection parameters are legitimate.

Pivot the edge x_{i-1} y_{i-1} z_{i-1} about the z_{i-1} hub through a point θ_i .

Decipher the present edge x_{i-1} y_{i-1} z_{i-1} along the z_{i-1} pivot by d_{i-1} unit.

Decipher the present casing x_{i-1} y_{i-1} z_{i-1} along the present x_i hub by a_i unit.

Pivot the present casing x_{i-1} y_{i-1} z_{i-1} along the present x_i hub by a_i unit.

Fig. 4 demonstrates that the finger has four casings with three joints. The primary casing otherwise called the base edge is x_0, y_0, z_0 and the resulting edges are allotted according to the fig. beginning with x_1, y_1, z_1 and finishing with x_4, y_4, z_4. The forward kinematic arrangement of a finger will be allotted utilizing homogenous network.

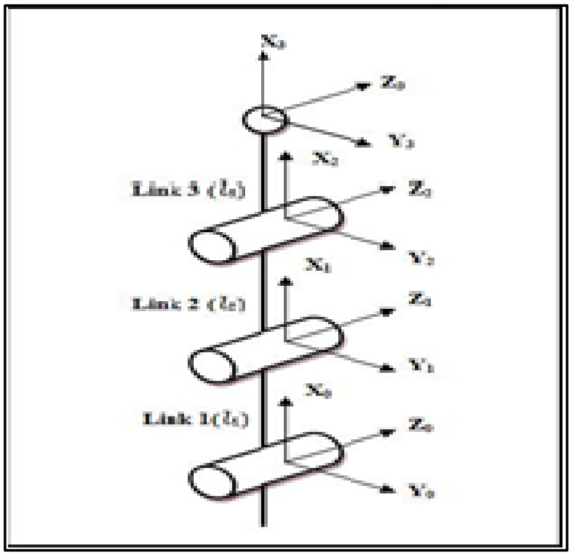

Figure 4: Model of a finger

Forward Kinematic

Forward Kinematic is utilized to decide the position and introduction of MFRH to decide the position and introduction of the robot hand in respect to the robot base arrange framework. The deduction of forward kinematic condition in light of Table 1.

i	θ_i	d	α_{i-1}	α_{i-1}
1	θ_1	0	0	0
2	θ_2	0	l_1(MCP)	0
3	θ_3	0	l_2(PIP)	0
4	0	0	l_3(DIP)	0

$$T_{i-1}^{i} = \begin{bmatrix} c\theta_i & -s\theta_i & 0 & \alpha_{i-1} \\ s\theta c\alpha_{i-1} & c\theta c\alpha_{i-1} & s\alpha_{i-1} & s\alpha_{i-1}d_i \\ c\theta s\alpha_{i-1} & c\theta c\alpha_{i-1} & c\alpha_{i-1} & c\alpha_{i-1}d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

$$T_0^1 = \begin{bmatrix} C_1 & -S_1 & 0 & 0 \\ S_1 & C_1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

$$T_1^2 = \begin{bmatrix} C_2 & -S_2 & 0 & l_1 \\ S_2 & C_2 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

$$T_2^3 = \begin{bmatrix} C_3 & -S_3 & 0 & l_2 \\ S_3 & C_3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \text{and}$$

$$T_3^4 = \begin{bmatrix} 1 & 0 & 0 & l_3 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

Hence the forward kinematics for the fingers of robot hand are given by

$$T_0^4 = [T_0^1 \quad T_1^2 \quad T_2^3 \quad T_3^4] \quad (3)$$

Inverse Kinematics

To discover the point joint of MFRH, the conditions is inferred utilizing the deduction of Inverse Kinematics. Fig. 5 speaks to the flexion of edges of one finger where l_1 to l_3 are finger parts and θ_1 to θ_3 are the joints in the middle of and speaks to the edges.

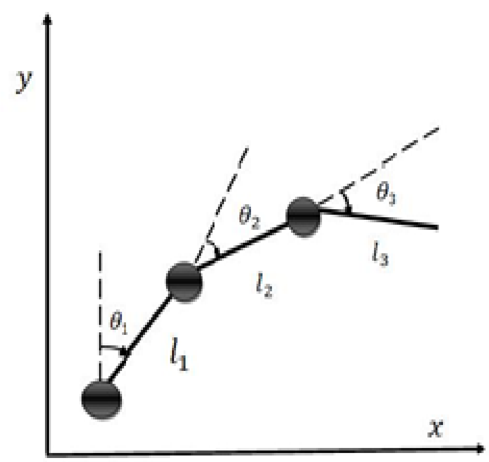

Figure 5: Orientation of one finger

By using the previous forward kinematic homogeneous matrices, we assume that

$$T_0^1 = \begin{bmatrix} C_{123} & -S_{123} & 0 & l_1C_1 + l_2C_{12} \\ S_{123} & C_{123} & 0 & l_1S_1 + l_2S_{12} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (4)$$

By using the previous forward kinematic homogeneous matrices ,assume a given orientation in the following

$$T_i^n = \begin{bmatrix} C_\phi & -S_\phi & 0 & x \\ S_\phi & C_\phi & 0 & y \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{5}$$

Jacobian

The next stepis Jacobian matrix .Jacobian is a relationship between joint space velocities with task space velocity.Hence velocity of the frame

$$\begin{aligned} x &= l_1 \cos\theta_1 + l_2 \cos(\theta_1+\theta_2) + l_3 \cos(\theta_1+\theta_2+\theta_3) \\ y &= l_1 \sin\theta_1 + l_2 \sin(\theta_1+\theta_2) + l_3 \sin(\theta_1+\theta_2+\theta_3) \\ \lambda &= \theta_1+\theta_2+\theta_3 \end{aligned} \tag{6}$$

Or

$$\begin{aligned} x &= l_1 C_1 + l_2 C_{12} + l_3 C_{123} \\ y &= l_1 S_1 + l_2 S_{12} + l_3 S_{123} \\ \lambda &= \theta_1+\theta_2+\theta_3 \end{aligned} \tag{7}$$

Hence the Jacobian become

$$J(\theta) = \begin{bmatrix} -l_1S_1 - l_2S_{12} - l_3S_{123} & -l_2S_{12} - L_3S_{123} & -l_3S_{123} \\ l_1C_1 + l_2C_{12} + l_3C_{123} & l_2C_{12} + l_3C_{123} & l_3C_{123} \\ 1 & 1 & 1 \end{bmatrix} \tag{8}$$

Dynamic

In light of the Fig. 5, the Lagrangian strategy was utilized to infer the elements. In element part, the conditions have been determined to discover the torque of MFRH. Alluding to the determined forward kinematics,

$$\begin{aligned} x &= l_1 \cos\theta_1 + l_2 \cos(\theta_1+\theta_2) + l_3 \cos(\theta_1+\theta_2+\theta_3) \\ y &= l_1 \sin\theta_1 + l_2 \sin(\theta_1+\theta_2) + l_3 \sin(\theta_1+\theta_2+\theta_3) \end{aligned} \tag{9}$$

The kinetic energy in matrix form can be written as

$$E_k = \frac{1}{2}\begin{pmatrix} \dot{\theta}_1 & \dot{\theta}_2 & \dot{\theta}_3 \end{pmatrix} \begin{bmatrix} Z_{11} & Z_{12} & Z_{13} \\ Z_{21} & Z_{22} & Z_{23} \\ Z_{31} & Z_{32} & Z_{33} \end{bmatrix} \begin{Bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \\ \dot{\theta}_3 \end{Bmatrix} \tag{10}$$

Where,

$$\begin{aligned} Z_{11} &= \frac{1}{4}m_1 l_1^2 + m_2\left(l_1^2 + \frac{1}{4}l_2^2 + l_1 l_2 C_2\right) + m_3\left(l_1^2 + l_2^2 + \frac{1}{4}l_3^2 + 2l_1l_2C_2 + l_1l_3C_{23} + l_2l_3C_3\right) + l_1 + l_2 + l_3 \\ Z_{12} &= \frac{1}{2}\left[m_2\left(\frac{1}{2}l_2^2 + l_1l_2C_2\right) + m_3\left(2l_2^2 + \frac{1}{2}l_3^2 + +2l_1l_2C_2 + l_1l_3C_{23} + l_2l_3C_3\right) + l_2 + l_3\right] \\ Z_{13} &= \frac{1}{2}m_3\left(\frac{1}{2}l_3^2 + l_1l_3C_{23} + l_2l_3C_3\right) + l_3 \\ Z_{12} &= Z_{21} \\ Z_{22} &= \frac{1}{4}l_2^2 m_2 + m_3\left(l_1^2 + \frac{1}{2}l_3^2 + l_2l_3C_{23}\right) + l_2 + l_3 \\ Z_{23} &= \frac{1}{2}m_3\left(\frac{1}{2}l_3^2 + l_2l_3C_3\right) + l_3 \\ Z_{31} &= Z_{13} \\ Z_{32} &= Z_{23} \\ Z_{33} &= \frac{1}{4}m_3l_3^2 + l_3 \end{aligned} \tag{11}$$

The potential energy is

$$E_P = \frac{1}{2}m_1 g l_1 S_1 + m_2 g\left(l_1 S_1 + \frac{1}{2}l_2 S_{12}\right) + m_3 g\left(l_1 S_1 + l_2 S_{12} + \frac{1}{2}l_3 S_{123}\right) \tag{12}$$

The Langrangean is computed as

$$L = E_k - E_P \tag{1}$$

By using the Lagrange-Euler Formulation, The equation of motion for three degree of freedom finger can be written as

$$\frac{d}{dt}\left(\delta \Big/ \delta \dot{\theta}_i \right) - \delta \Big/ \delta \dot{\theta}_i = \Gamma_i \tag{2}$$

Thus, this completes the mathematical modelling of MFRH. These equations are used in the simulation of the design of MFRH.

CONCLUSION

The scientific displaying assumes a noteworthy part in renovation of multi fingered robot hand (MFRH). This paper manages the numerical demonstration which contains the kinematics and flow of MFRH for empowering the rebuilding work. In the proposed demonstration the displaying is done by utilizing Euler-langrangean method and Denavit Hartenberg calculation. The hypothetical examination of the model has been completed.

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