MATHEMATICAL MODELING AND KINEMATIC ANALYSIS OF A TENDON DRIVEN ROBOTIC HAND

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Abstract: In this paper the finger has been outlined by taking the human hand as a model. Consequently a ligament incited finger has been considered, where a coupling ligament is acquainted with force a coupling between the developments of the last two joints, similitude to the human hand. The finger is constituted by a 4-DOF mechanical structure, whose kinematics is depicted considering the fingertip position as end. The finger is activated by methods for four ligaments i.e. three agonistic ligaments and one rival ligament. An extra non-impelled ligament is utilized to couple the developments of the last two joints i.e. medial and distal joints inside the finger structure.

Keywords: coupling, kinematics, agonistic ligament

1. Introduction

Human Hand is the most modern and complex external limit on human body. The hand is a standout amongst the most intricate and load bearing part which goes about as an information (material detecting) and in addition yield (physical work) gadgets to human. Human hands can overwhelmingly adjust to objects with self-assertive shape and size amid getting a handle on. David [1] has given an arrangement space portrayal of the kinematics of the fingers in addition to protest framework for multi fingered control. Emily [2] has determined kinematics and progression conditions in the plan of a human automated hand for space operation. Parasuraman and Shiau [3] have determined kinematics and flow conditions for bio-mechanical examination of human joints. Parasuraman [4] has enhanced kinematics deduction for humanoid robot controllers to be utilized as a part of the recreation MFRH utilizing virtual reality tool compartment. Valentinetal. [5] have given induction for direction arranging of a robot controller. Kevin and Thurston [6] have inferred kinematics examination of novel 6 DOF parallel controller. This kinematic investigation is utilized for three elbow points before processing the position and introduction of the top plate. Mina et al. [7] have utilized reverse kinematics to locate the joint of the robot finger. In dynamical model, Yavin [8] has inferred the kinematic and element for three-interface controller. Jonker and Aarts [9] have enhanced element reproduction for the planar adaptable connection controller. Panagiotis and Kostas [10] have enhanced the kinematics and element to discover the position and compel of the robot arm in application to teleportation and orthosis. Ronen et al. [11] have utilized kinematics and element conditions for the planary adaptable incited parallel robot. Aaron [12] has determined forward and backwards kinematic for naturally propelled capable robot hand. Ramasamy and Arshad [13] likewise have inferred the condition of kinematic and element to the robot hand recreation utilizing 30 Studio Max and Maya 30. The preparatory aftereffects of the review were exhibited in the ICORAFFS meeting procedures [14].

Modeling and analysis:

A Human hand has 23 DOF that is given by 17 joints [15]. On the off chance that three dimensional developments are mulled over, degrees of flexibility increment to 29 in view of introduction and position variety of the hand. The joint of a multi-fingered robot hand is appeared in Fig.1The phalanges are the little bones that constitute the skeleton of the fingers and thumb. The closest phalange to the hand body is called proximal phalange and the one toward the finish of the each finger is called dista phalange. The joints of the finger, the distal inter phalangeal (DIP) and proximal interphalangeal (PIP) joints have 1 DOF having rotational development and meta carpo phalangeal (MCP) joint has 2 DOF attributable to adduction-kidnapping and rotational movements. But the thumb, the other four fingers (file, center, ring and little fingers) have comparable structure as far as kinematics and elements highlights. Thumb is the most complex physical structure among the

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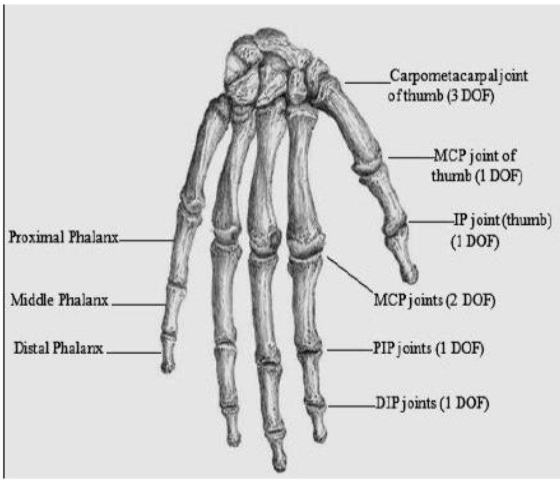
hand fingers and unique in relation to the fingers in that contains just two phalanges and has 5 DOF [16].The life systems of a solitary finger is appeared in fig-2



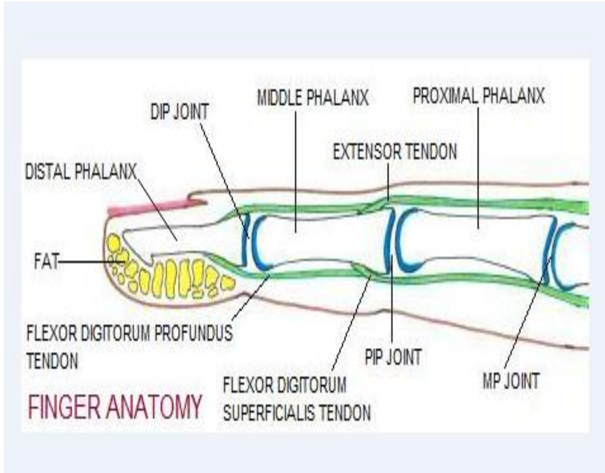
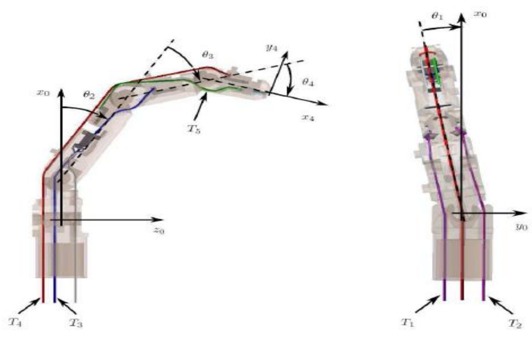


Fig-1 Human Hand Structure **Fig-2 Structure of a Single Finger**

The finger has been outlined by taking the human hand as a model. thus a ligament impelled finger has been considered. Here a coupling ligament likewise called detached ligament is acquainted with force a coupling between the developments of the last two joints, like the human hand. The model of a solitary finger is appeared in fig.3. The finger is activated by methods for four ligaments: three agonistic ligaments and one rival ligament. An extra non-impelled ligament is utilized to couple the developments of the last two joints i.e. medial joint and distal joint inside the finger structure. This ligament arrangement is referred to in writing as a "N+1" ligament organize design [17], since all joints share an enemy ligament. The ligaments are settled to the phalanges and directed inside the finger through appropriate planned trenches, as appeared in Fig.4. The ligament are constituted by Fistfight links: a total investigation on the ligament transmission demonstrating, control and material choice is accounted for in [18].



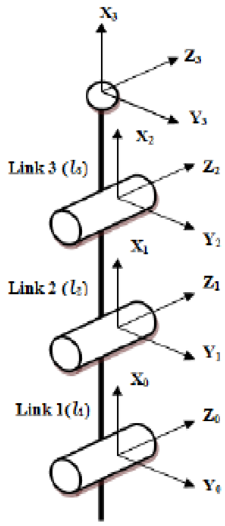


Fig-3 Model of a Single Finger **Fig-4 Structure of a Single Finger with Tendons**

the finger is constituted by a 4-DOF mechanical structure, whose kinematics considering the fingertip position as end-point is described by the Denavit-Hartenberg parameters summarized in Tab1. Tendon pathways have been designed so that tendons envelope on curved surfaces with constant radius along the entire joints movement range, leading to a linear relation between tendon and joint displacements.

Link	d	θ	r in met	α in rad

1	0	θ_1	r_1=0.020	$\pi/2$
2	0	θ_2	r_2=0.045	0
3	0	θ_3	r_3=0.0299	0
4	0	θ_4	r_4=0.0218	0

Table1: Denavit-Hartenberg parameters of the Finger

it is possible to compute the fingure tip position P_{eff} with respect to the Denavit-Hartenberg parameters of the finger in Table1 the base reference frame:

$$P_{eff} = \begin{bmatrix} c_1(a_1 + a_2c_2 + a_3c_{23} + a_4c_{234}) \\ (a_1 + a_2c_2 + a_3c_{23} + a_4c_{234})s_1 \\ a_2s_2 + a_3s_{23} + a_4s_{234} \end{bmatrix} \quad [1]$$

Where S_{ijz} and C_{ijz}denote the functions sin ($\theta i + \theta j + \theta z$) and cos($\theta i + \theta j + \theta z$) respectively. The joint angle ranges are mechanically constrained by stroke limiters to intervals:

$\theta_1 \in [-\pi/18, \pi/18]$ $\theta_{\{2,3,4\}} \in [0.\pi/2]$ [rad] [2]

Link 0 is the base of the finger i.e. the hand palm. The other links, numbered from 1 to 4, correspond to abduction link, proximal, medial and distal phalanx respectively. The tendons are numbered from T1 to T5, as shown in fig-4

T1, T2: Tendons 1 and 2 drive the first two joints and are attached to link 2 i.e. proximal phalanx

T3: Tendon 3 drives the medial joint and is attached to the medial phalanx

T4: Tendon 4 is the antagonist tendon, attached to the distal phalanx.

T5: Tendon 5 is the passive tendon connecting the proximal with the distal phalanx.

Due to the particular design and neglecting the tendon elasticity, the relation between the vector of the joint angles $\theta = [\theta_1\ \theta_2\ \theta_3\ \theta_4]^T$ and the vector of tendon displacements $l = [l_1\ l_2\ l_3\ l_4\ l_5]^T$

$$\mathbf{H_C} = \begin{bmatrix} r_{11} & r_{21} & 0 & 0 \\ -r_{11} & r_{21} & 0 & 0 \\ 0 & 0 & r_{33} & 0 \\ 0 & -r_{24} & -r_{34} & -r_{44} \\ 0 & 0 & -r_{35} & r_{45} \end{bmatrix} \quad [3]$$

Where r_{ij} is the radius of the circular surface that tendon i envelops on joint j. The numerical value of r_{ij}isrepoted in table below

r_{ij}	r_{11}	r_{21}	r_{33}	r_{24}	r_{34}	r_{44}	r_{35}	r_{45}
Radius(mm)	5.6	4.4	5.2	6.1	5.2	4.8	4.8	4.3

Table-2: Radius of the finger circular surface

By considering l5 = 0, i.e. assuming that the tendon T_5 is inextensible, the last equation in 2.5 gives the kinematic constraint imposed by the passive tendon:

$$\theta_4 = \frac{r_{35}}{r_{45}}\theta_3 \quad [4]$$

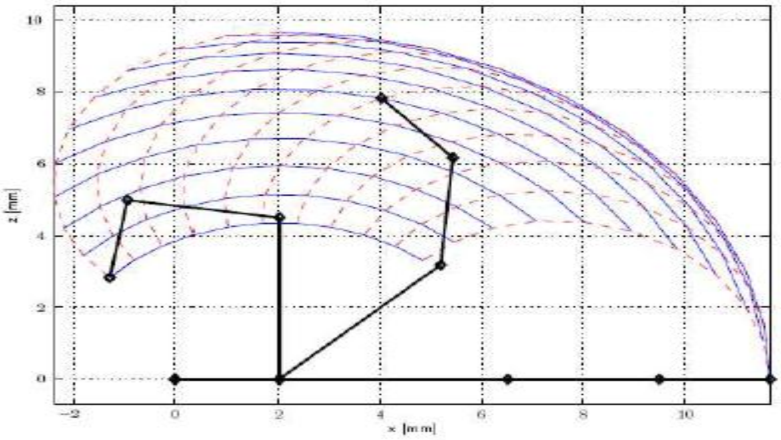


Fig-5 : Finger Workspace

On the other hand, assuming that tendon T5 has a linear elastic coefficientkt and friction is negligible [18], from (eq-3) it is possible to compute the relation between the force f_5 applied to the passive tendon and its elongation l5:

$$f_5 = -k_t l_5 = \begin{cases} -k_t(\theta_3 r_{35} - \theta_4 r_{45}) & l_5 > 0 \\ 0 & l_5 \leq 0 \end{cases}$$

Obviously $l_5 \leq 0$ means that the tendon is slacking: this condition must be avoided by adopting a proper control strategy. The finger workspace is shown in Fig.5, assuming the constraint in Eq.4.In the simulation model of the finger, the actuators have been modeled as ideal force generators that impose the force vector $f = \left[f_1^a \ f_2^a \ f_3^a \ f_4^a \right]$

Conclusion

This paper exhibited a model of a finger which is ligament incited in this way the figuring of the successful facilitate at the end effect or .it additionally centered around the examination of the sweep of the round surface that ligament creates on the joint. The three dimensional photo of the finger workspace are plotted. At last we have depicted a portion of the key focuses that will in all probability draw in specialists in future.

References

[1] David J. Mont ana, “The Kinematics of Multi-Fingered Manipulate ion”, *IEEE Transactions On Robotics And Automation*, Vol 11 ,No 4, August 1995.

[2] Emily, “Design Of An Anthropomorphic Robotic Hand For Space Operations”, Department of Aerospace Engineering, 2007.

[3] S. P arasuraman, and Ler Shiaw Pei, “ Bio -mechanical Analysis of Human Joints and Extension of t he Study t o Robot .” *Proceedings of World Academy Of Science, Engineering And Technology* Volume 29 May 2008 Issn 1307-6884, 2008.

[4] S.Parasuraman, “Kinematics and Control System Design of Manipulators for a Humanoid Robot”, *Proceedings of World Academy Of Science, Engineering And Technology Volume* ISSN 1307-6884 Pwaset Volume, 29 May 2008

[5] Valentines Grecu, Nicolae Dumitru, and Luminita Grecu, “ Analysis of Human Arm Joints and Extension of the Study to Robot Manipulato*r”, Proceedings of the International MultiConference of Engineers and Computer Scientists* 2009 Vol II IMECS 2009, March 18 - 20, 2009

[6] Kelvin and Thurston, “ Kinematic Analysis of 6 -DOF Parallel Manipulator, Proceeding of *IEEE International Conference on Robotic and Automation,* 1993.

[7] Mina Terauchi, Kouta Zenba and Akira Shimada, " T he cooperative control system of the robot finger using Shape Memory Alloys and Electrical Motors", *IEEE International Workshop on Advance Motion Control*, 2008.

[8] Y. Yavin, Control of a "Three-Link Manipulator with a Constraint on the Velocity of its End-Effect or", *Computers and Mathematics with Applications 40 (2000) 1263-1273,* 2000 International Journal of Basic & Applied Sciences IJBAS-IJENS Vol:09 No:10 68 96610-9696 IJBAS-IJENS © December 2009 IJENS I J E N S

[9] R.G.K.M. AARTS And J.B. JONKER, "Manipulators Using Adaptive Modal Integration Dynamic Simulation Of Planar Flexible Link." *Multibody System Dynamics* **7:** 31–50, 2002.

[10] Panagiotis K. Artemiadis and Kostas J. Kiriakopoulos, "EMG-based Position and Force Control of a Robot Arm: Application to Teleportation and Orthosis

[11] Ronen Ben-Horen, Morshe Shoham and Shlomo Djerassi, "Kinematic, Dynamic and construction of a Planarly Actuated Parallel Robot", *Medical Robotic Laboratory*, 1999.

[12] Ramasamy and M.R Arshad "Robotic Hand Simulation with Kinematics and Dynamic Analysis, *TENCON 2000.Proceddings*, 2000.

[13] Bundhoo, V., Park, E. J., "Design of an Artificial Muscle Actuated Finger towards Biomimetic Prosthetic Hands", 12th International Conference on Advanced Robotics ICAR Seattle, 2005.

[14] Wan Faizura,IrraivanElamvazuthiIrrairan and Elamvazuthi, *ICORAFSS 2009 Proceedings,* June 2009

[15] Wan Faizura, Irraivan Elamvazuthi Irrairan and Elamvazuthi, ICORAFSS 2009 Proceedings, June 2009

[16] S.C. Jacobsen, E.K. Inversen, D.F. Knutti, R. T. Johnson and K.B. Biggers, "Design of the Utah/MIT Dexterous Hand, Proceedings of the 1986 IEEE International Conference on Robotics and Automation, pp 1520-1532, 1986.

[17] B. Siciliano and O. Khatib (Eds.), *Springer handbook of robotics,* ch15, Robot Hands

[18] G. Palli, G.Borghesan, and C. Melchior, *Tendon-based transmission systems for robotic devices: Models and control algorithms*, IEEE International Conference on Robotics and Automation (2009)

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