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Design and Manufacture A 3D Printed Artificial Hand

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ABSTRACT: In spite of the different types of upper limb prosthetics that are available in the market now days, the researches should carry out to present a various methods and development in order to reach the optimum level in this field. This paper presents a methodology to design and manufacture an artificial hand for prosthetic application. The proposed design is a five finger hand with the forearm actuated by under-actuated system composed of tendons and servomotors. The manufacture strategy started by design the model using the solidworks software and manufacture by 3d printing technique. it possess 15 Dof, 3dof for each finger. Analyzing of the forward kinematics had also been carried out using the matlab robotic toolbox to present the workspace and fingertip coordinates. The hand was tested to perform gesture movements and some grasping movement by using a myoelectric control system, and it was able to approximates the manipulation abilities of human hand very well.

Artificial hand, Solidworks, hand kinematics, 3D printing

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I. INTRODUCTION

The loss of upper extremity has two unique income for the amputee: unexceptional decrease of the usefulness(the amputee gets to ne distinctly not able to complete a large portion of the control and getting handle on undertaking) and the start of mental inconvenience (the removal adjust the restorative appearance of upper extremity). The use of a prosthetic devise returns the amputees independence, which also leads to increase confidence and well-being. [1]

Over the last decades there have been great strides in the development of prosthetic hands and terminal devices moving towards more dexterous hand devices, however even combination of high functionality, durability, adequate cosmetic appearance, and affordability. Researches and developments had carried out to produce a well functional terminal dexterous devises [2]

In Carroza,M, Cappiello,G they developed a myoelectric prosthetic hand fabricated as a single piece in molding strategy by using soft materials. with a tendon driven compliment mechanism made in single part not in assembly with 10 DOFs actuated by one motor present in the palm and controlled by EMG signal generalized from forearm muscles collected by a couple of electrodes and controlled in a threshold manner .[3]

In Wiste,T, Dalley,,S a new design was presented and developed to acquire a complete grasp taxonomy composed of eight required hand postures with the possibility of controlling them by EMG signals. The design was five fingers anthropomorphic hand with 16 joints driven by five independent actuators located in the forearm with tendon- driven mechanism containing torsional spring in the joint. The eight required grasp was achieved and a force and speed capabilities of the device was presented. [4]

JiangY, Hoshigawa S, Presents a simplified EMG prosthetic hand that intended to be lightweight, low cost and easy to use by an amputee in real life situations; the hand was based upon tendon-driven mechanism actuated by two motors, and controlled by sEMG signal collected by two types of electrodes conductive polymer and the other stainless nonwoven sheet in a number of 6 electrodes for 3 channels. The signal control is established by 32–bit microprocessor. [5]

This paper propose a method to design and manufacture an anthropomorphic artificial hand for prosthetic application. the design proposed is a five finger hand manufactured by the 3D printing technique actuated by tendons and servo motors. The servos located at a forearm. it possess a 15 Dof, 3 for each finger depending on the number of joints. The design was done using the solidwork software and an analysis of the forward kinematic of the fingers was done using matlab toolbox. The hand was tested to perform some essential movements taking order from a myoelectric based controller.

II. METHODOLOGY SOFTWARE DESIGN

Since solidworks is introduced, it has been a great tool to every engineer who is interested in designing. It is a complete Cad package that offers modeling of complicated structure as parts
beforEach finger is constructed from three phalanges (Except the Index) that are
considered as the links while the joints consist of a wheel and a pin, a wheel that is connected to tendon and pin to support the hinge.
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considered as the links while the joints consist of a wheel and a pin, a wheel that is connected to tendon and pin to support the hinge.
It is worth noticing that the three fingers (little, ring, middle) only differ in the max length, while the index has an extra phalange that is connected to the palm which allows
the abduction and adduction of the index. On other hand, the thumb has a different
design, depending on its functions and movements. The third phalange of the thumb allows abduction and adduction of the thumb in the perpendicular line to the palm.

The palm is constructed of only one part in a very sophisticated design to be the
center that connects the fingers and the forearm. It has grooves to allow the flow of tendons from the actuators which are located in the forearm. These grooves ensure that the tendons for each finger will not interrupt with others and also constrain its movement in a specific area which makes the control of movement easy to some point. The forearm is constructed of two main sections each contains three parts connected together.

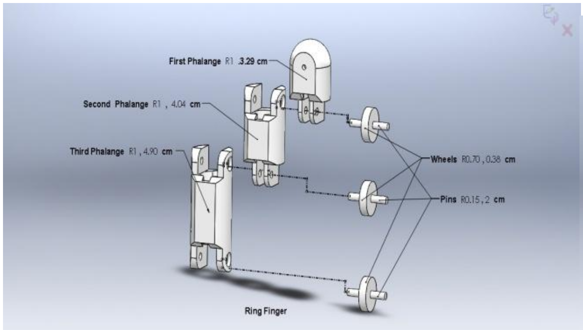


Figure 0-1Ring Finger Parts

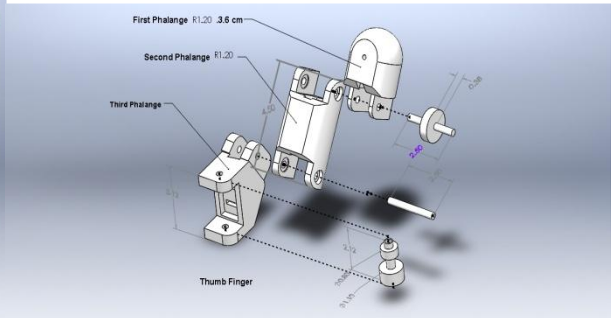


Figure 0-2Thumb Finger Parts

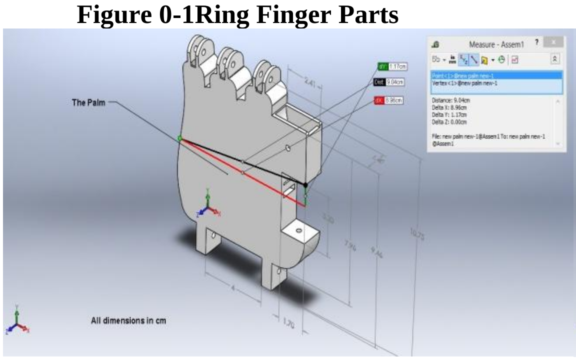


Figure 0-3Palm

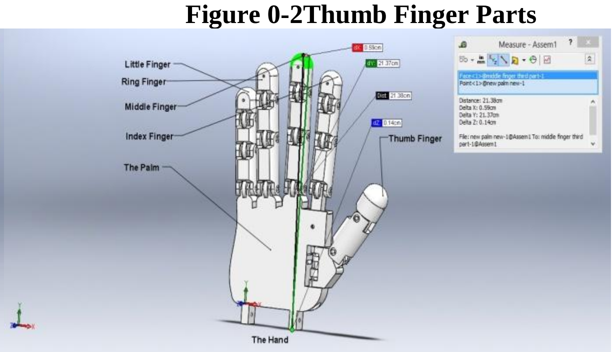


Figure 0-4Complete Hand

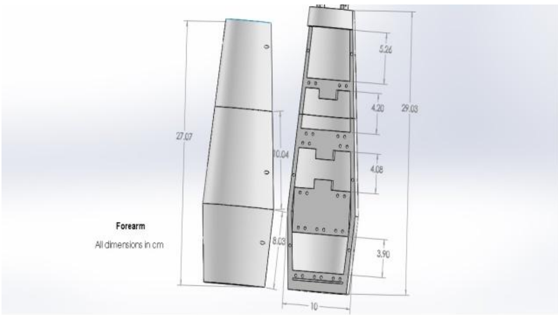


Figure 0-5Forearm

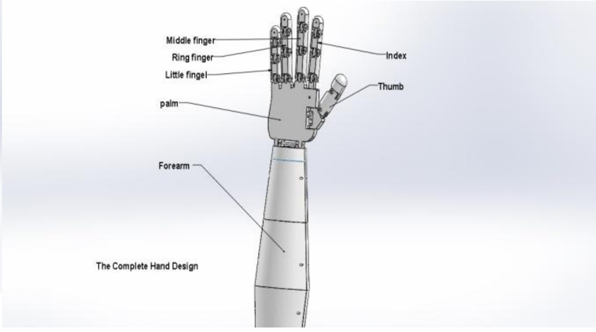


Figure 0-6Hand and Forearm

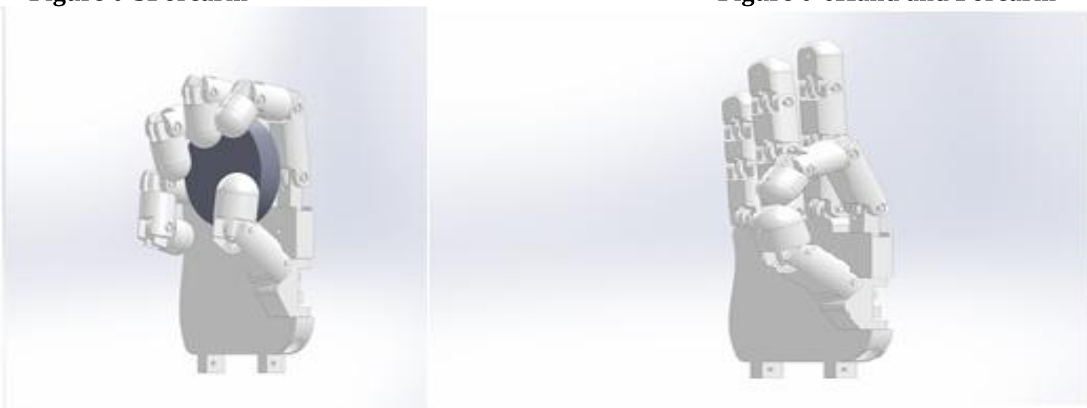


Figure 0-7Simulated of some hand movements

2.2. Finger Kinematics

In the proposed design, sum of three revolute joints are utilized, every joint speaks to a single DOF, and accordingly, every finger possess three DOFs, each joint provides 90° of movement in both extension and flexion.

The movement starts from the first phalanx then the second phalanx until the last (the third phalanx). Thus, the second and last joints will depend in their movement on the first joint in sequence; each will finish it's 90° rotation then the second start. The thumb on other hand has one different movement to insure the abduction and adduction, , this movement is represented by the last phalanx which will have its independent movement, i.e the second will have depend on the first while the third will move by its own and as well, each joint will have 90° movement in rotation.

The kinematics demonstrates assumes an imperative part in the work as it gives the requirements on the x-y plane coordinate of the finger. Utilizing the D-H (Denavit – hartenberg) representation, we start by tackling the issue of forward kinematics where single link changes are binded to yield a solitary transform that totally depict the position and orientation of fingertip as for the reference casing of the base (the palm). At that point, the equations of inverse kinematics are dissected from quadrilateral [6].

Kinematics can be defined as the study of the motion of robot. The investigation calculates the positions of the robot's links without coming back to the forces bringing on the movement.

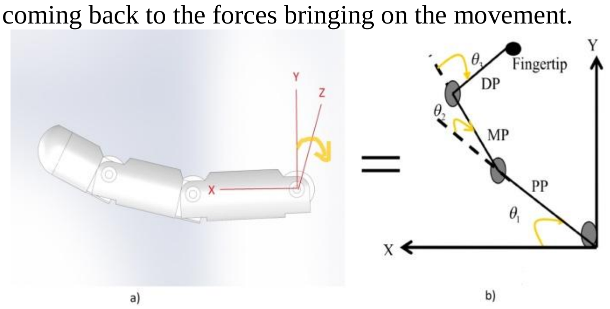


Figure 0-8 (a) Prototype of prosthetic finger ,(b) Schematic of prosthetic finger lying in the X-Y plane

Table 0-1D-H Parameters of the four fingers

Joint	Twist α_i	Length L_i	Offset d_i	Angle θ_i

1	0	L_1	0	θ_1
2	0	L_2	0	θ_2
3	0	L_3	0	θ_3

Table 0-2D-H parameters of the thumb

Joint	Twist α_i	Length L_i	Offset d_i	Angle θ_i
1	$\pi/2$	L_1	0	θ_1
2	0	L_2	0	θ_2
3	0	L_3	0	θ_3

Each finger is considered as three link manipulator, thus the homogenous transformation that represents the coordination of finger fingertip which is:

$$^0T_3 = \begin{bmatrix} c_{123} & -s_{123} & 0 & L_1c_1 + L_2c_{12} + L_3c_{123} \\ s_{123} & c_{123} & 0 & L_1s_1 + L_2s_{12} + L_3s_{123} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$^0T_3 = \begin{bmatrix} x_i & y_i & z_i & p_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Where:

$$c_{123} = \cos(\theta_1 + \theta_2 + \theta_3)$$

$$s_{123} = \sin(\theta_1 + \theta_2 + \theta_3)$$

$$c_{12} = \cos(\theta_1 + \theta_2)$$

$$s_{12} = \sin(\theta_1 + \theta_2)$$

$$c_1 = \cos\theta_1$$

$$s_1 = \sin\theta_1$$

$[x_i, y_i, z_i]$ = orientation matrix of the ith coordinate system established at link I with respect to base coordinate frame. Upper left 3*3 partitioned matrix of ^0T_i.

p_i =position of vector pointing from origin of base coordinate system to origin of the ith coordinate system. Upper 3*1 partitioned matrix of ^0T_i.

The solution for the position of the fingertip is found as given as :

$$P_{x_{fingertip}} = L_1\cos\theta_1 + L_2\cos(\theta_1 + \theta_2) + L_3\cos(\theta_1 + \theta_2 + \theta_3)$$

$$P_{Y_{Fingertip}} = L_1\sin\theta_1 + L_2\sin(\theta_1 + \theta_2) + L_3\sin(\theta_1 + \theta_2 + \theta_3)$$

$$P_{Z_{fingertip}} = 0$$

$$\phi = \theta_1 + \theta_2 + \theta_3$$

Where

$P_{x_{fingertip}}$, $P_{Y_{Fingertip}}$, $P_{Z_{fingertip}}$ = position of fingertip in x,y and z coordinate (cm).

L_1, L_2, L_3 = lengths of 1^{st} link , 2^{nd} link and 3^{rd} link.(cm).

$\theta_1, \theta_2, \theta_3$ = Joint angle of 1^{st} joint , 2^{nd} joint ,and 3^{rd} joint.

ϕ = angle between reference or orientation frame and fingertip.

2.3. Hand Manufacturing

The prosthetic hand was built by using the additive manufacturing .commonly referred to as 3D printing, which is a method to construct almost any computer aided design (CAD) model using thermoplastics such as the ABS, PLA, and PET. This method promises customization, simplicity with low cost. The application of this method to fabricating parts suited to address local needs in developing countries has become of interest in recent years. The application of 3D printing in low-income countries, especially using open source designs, holds much promise for delivering a whole range of desired equipment on demand. Actually, the technology has been used to deliver humanitarian aid to those in need [1]

Each finger of the hand is actuated by a servo motor located at the forearm except the thumb which is connected to two servo motors .the servo motors used are (Tower Pro mg995) servomotors, a smart motor with integrated speed reducer, controller and driver function. It has a compact size with a big torque generation due to the efficient speed reduction; The parts of the forearm were assembled with the metal screws and the motors were set inside the case of the forearm and fastened with screws in the specified positions.

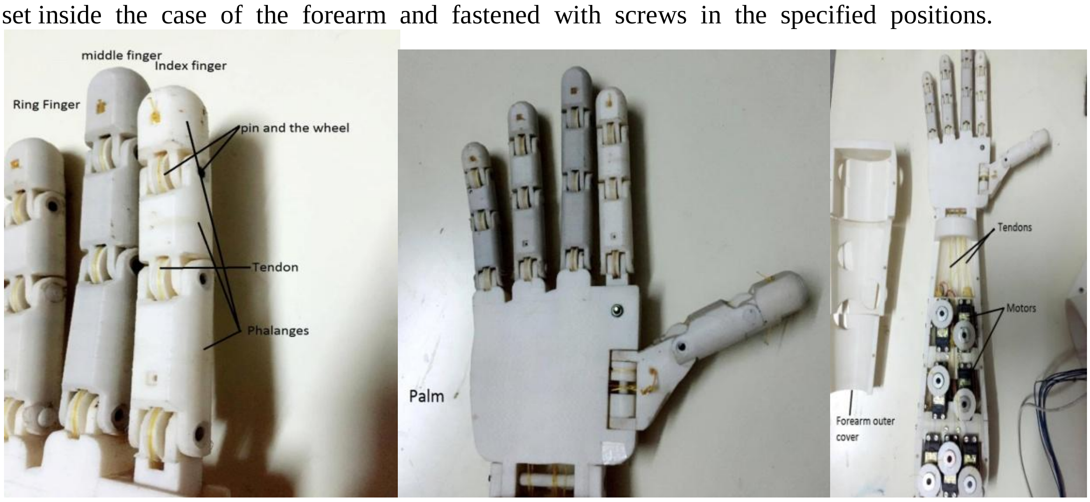


Figure 0-9Complete Manufactured Hand

III. RESULT

3.2. Kinematic result

Using the robotic toolbox in matlab, we established the workspace coordinates of each finger with concerning the joint angles, using the D-H (Denavit – hartenberg) method.

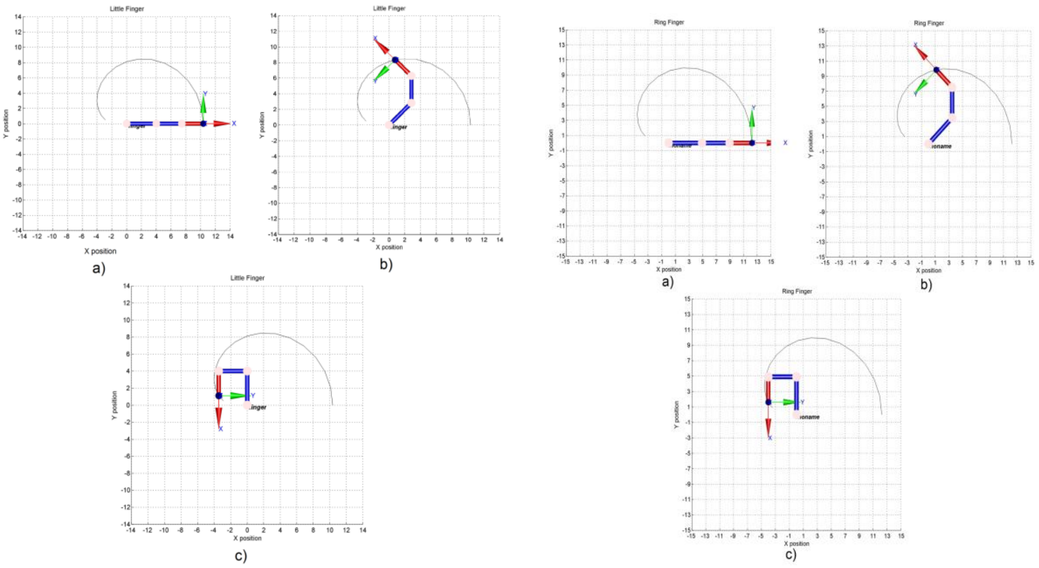


Figure III-1 Positions of little finger and ring finger at joints angles: a) 0°, b) 45°, c) 90° with the generated workspace

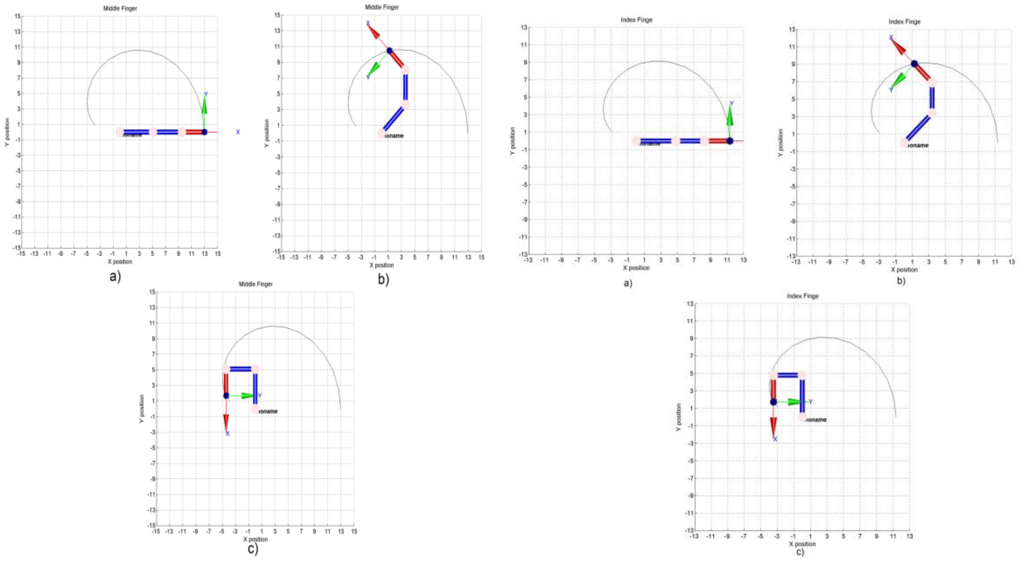


Figure III-2 Positions of middle finger and index finger at joints angles: a) $0°$, b) $45°$, c) $90°$ with the generated workspace

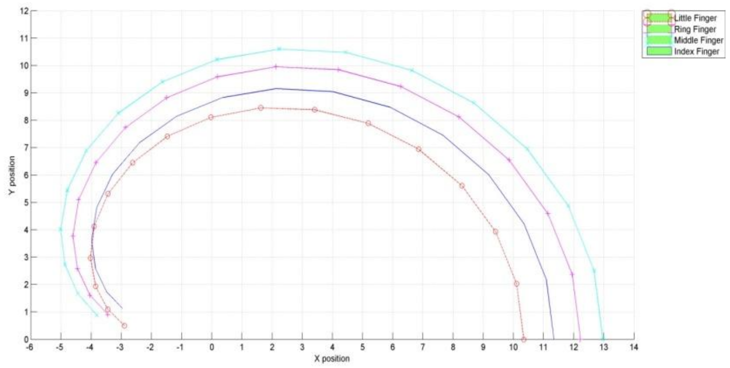


Figure III-3Fingers workspace

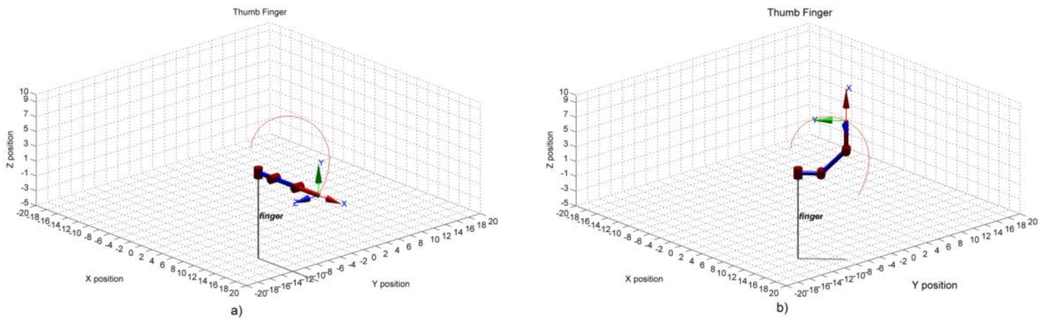
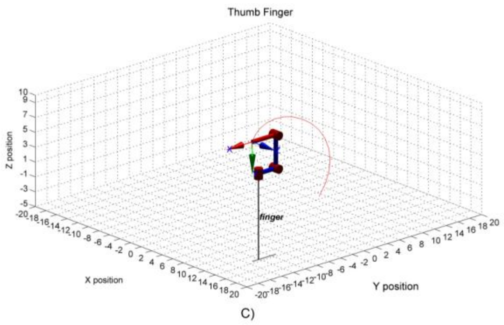


Figure III-4Thumb position at joints angles a) $0°$, b)$45°$



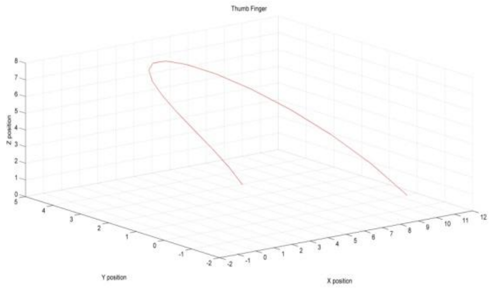


Figure III-5Thumb position at joints angles = 0°Figure III-6Thumb workspace

Table 4-1Maximum Px and Py of fingertips of the Fingers

Little finger	Px fingertip	Py finger tip
max	10.3500	8.4802
min	-4.0261	0

Middle finger	Px fingertip	Py finger tip
max	12.97	10.6212
min	-5.0119	0

Ring finger	Px fingertip	Py finger tip
max	12.23	9.9775
min	-4.6058	0

Index finger	Px fingertip	Py finger tip
max	11.35	9.1724
min	-3.9889	0

Table 4-2Maximum fingertip Px,Py and Pz of the thumb

Thumb finger	Px fingertip	Py finger tip	Pz finger tip
max	11.45	4.6	7.44
min	-0.052	-1.05	0

3.3. Hand Final Movements

The artificial hand was set to test for the following movements: Full hand extension and flexion, four finger extension and flexion, Pinch, Grasp of cylindrical object, Grasp for full rounded object. Using a myoelectric based controller system composed of myoware muscle sensor and Arduino the hand was controlled by the EMG signal generated from single electrode position at the forearm.

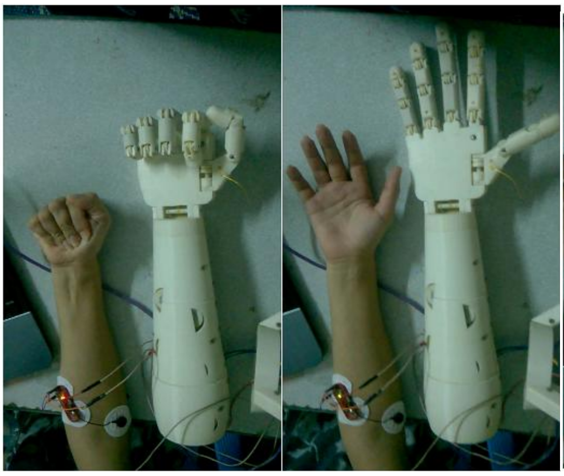
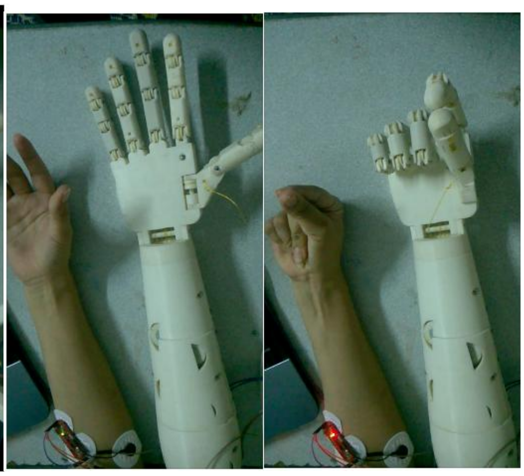



Figure III-7Full hand flexion / extension   Figure III-8Pinch

Figure III-9 Grasp of large cylindrical object

Figure III-10Grasp of rounded small object

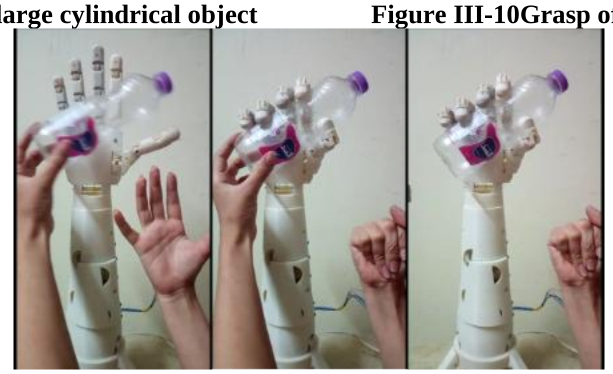


Figure III-11Grasp of small cylindrical object

IV. CONCLUSION

The artificial hand designed approximates the manipulation abilities of human hand very well. A number of gesture movements are produced and number of variety objects can be grasped in a natural way. The five fingers have 15 degrees of freedom driven by six actuators (each actuator for each finger) which enables the movements of each finger independently which offers more manipulation abilities. The kinematic analysis of the finger showed that: as the finger length increased, the corresponding workspace envelope also increased which made the middle finger possess the biggest workspace. Increasing the workspace of the fingers means increasing of the workspace of the artificial hand when it comes to grasping. It also showed that the thumb is able to work in two planes due to the design of the third phalanx which makes it mimic the exact movement of the human thumb.

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