SMART PHONE CONTROLLED 3D PRINTED PROSTHETIC HAND (KU HAND) FOR BELOW ELBOW AMPUTEE

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***Abstract*—This paper presents an anthropomorphic (having human like characteristics), open source, light-weight and affordable prosthetic hand that can be controlled using android phone via Bluetooth designed for use by people with trans- radial (below the elbow) amputations residing in low income countries. The hand can perform four basic functions: gripping with all fingers closed, all finger release, pinch with three fingers and lateral hold using thumb. It can be used by a below elbow amputee with a pre-existing stump to perform basic operations and also can be used for research purpose. It mostly uses common materials and can be easily reproduced using rapid prototyping techniques such as 3D printing. It has got both qualitative and quantitative features comparable to that of commercial prosthetics but costs only about one-fifth of commercial prosthetic. It was designed to be functionally and aesthetically efficient. The delay time for this prosthetic hand is about 2 to 3 seconds.**

Keywords—prosthetic hand, below elbow amputees, 3D printing

I. INTRODUCTION

Amputation is taken from the Latin term “amputare” meaning “to cut out” is the removal of a limb by trauma, medical illness, or surgery, as a surgical measure used to control pain or a disease process in the affected limb. Due to continuous growth in industrialization and lack of awareness in safety parameters the cases of amputations are growing[1].

A prosthesis (also called a prosthetic limb, artificial limb, or limb "replacement"— though natural limbs are irreplaceable) is an artificially made substitute for a limb lost through a congenital defect (present at birth), accident, illness, or wartime injury [2]. The loss of one hand can significantly affect the level of autonomy and the capability of performing daily living, working and social activities[3]. For people missing an upper-limb, lack of a prosthetics is a major disability that affects their quality of life. Missing limbs can lead to social exclusion, and difficulty in gaining meaningful employment.

In developing countries, the availability of prosthetic devices is extremely limited, yet the demand there is the greatest. Studies in the field of prosthesis have been conducted since the time of World War II that is since early 1940s [4]. Several researches have been conducted for the advancement in prosthetic hand. The modern prosthetic hand has been designed closely approximate to natural limb in both form and function[5].

The project was focused on getting prosthetic to those amputees who need them. The project was designed as low-cost and functional 3D printed upper-limb prosthesis device. With the prosthetic hand, amputees can regain function, improve their quality of life, and may have better access to employment opportunities.

The major objective of this project is to design an affordable and motorized prototype prosthetic hand that can be controlled using android phone via Bluetooth for below elbow amputee and fabricate it using 3D printer and locally available materials.

II. MATERIALS AND METHODOLOGY

The prosthetic hand is designed to be functionally and aesthetically efficient while keeping the affordability in mind. The design of prosthetic hand considers three major design areas: Structural design, kinematic design and control system design.

A. Structural Design

This section gave shape to the hand and held all the parts together. It consists of upper and lower parts of five different fingers, palm and its cover and wrist mount. All the parts were first modelled in software and then fabricated using 3D printer. The printing material used was PLA. It consisted of following parts:

1) Upper Palm

The main purpose of this part is to provide a base to the fingers and help to fix all five of the motors in place. It also acts as a guide for the locally designed linear actuator in Design lab.

2) Lower Palm

Lower palm is designed to cover and lock the linear actuators in place. It is curved shape makes the hand look more natural and help in gripping objects.

3) Lower Wrist

The lower wrist supports the hand while showcasing and also it held all the electronics together.

4) Upper Wrist

It covers as well as locks the electronics together.

5) Finger Tip

It's design resembles a combination of human distal and intermediate phalanges and helps to perform various tasks for the hand. It has the provision of adding soft material for enhanced gripping.

6) Finger Base

Finger tip is supported by the finger base which plays a vital role for the linkage mechanism. It is designed based on the proximal phalanges of a human finger.

7) Thumb Support

It is designed to support the upper portion of thumb and help it rotate on its axis.

B. Kinematic Design

This section facilitates the movement of individual fingers and consists of actuators, linear actuating mechanism and its couplings and connectors. Micro servo motors powered actuators create motion of individual fingers in the hand.

This section consisted of following components:

1) Coupling

It connects the shaft of the motor and head of the nut used for actuation. Four coupling has been used in the hand.

2) Linear Actuator

It converts the rotation of the motor into linear motion. The mechanism is based on M5 nut & bolt which is commonly available.

3) Actuating Connector

It connects linear actuator with the lower finger and plays vital role in creating the motion of the finger.

4) Linkage Connector

It connects the upper finger with the base of the upper palm. It works as a fixture for mechanism of the finger.

5) Thumb Coupling

It is specifically designed for the thumb to connect the motor shaft with the string and create the motion of the thumb. All the components are assembled using M2 nut & bolts.

C. Control System Design

This is the brain of the hand which controls all the mechanism and components. It takes input from user and directs hand to perform desired operations. A Bluetooth module is used to receive the input from a smart phone which has an locally developed application. The application provides user the movement options and is designed to send the signal to the prosthetic hand. The control system is powered by an Arduino to receive, process and direct the drive fingers based on the user's choice. A lithium polymer (Li-Po) battery is used to power the circuit along with a power switch to turn on the electronics.

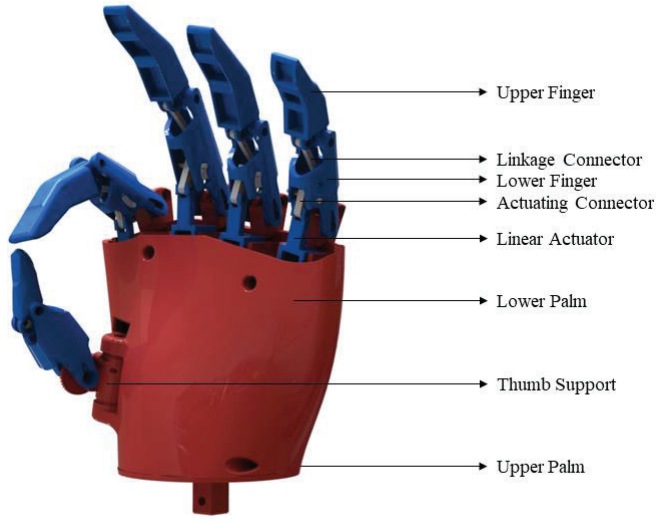

Fig 1. Rendered 3D model of the prosthetic hand showing different labelled parts

Fig 2. Rendered 3D model of the lower palm showing motor holding sockets

D. Methodology

The hand was made in various steps as shown in fig 3. First, various similar projects, books, papers and commercial devices were studied to generate a concept of the project. Then, the concept was used to develop a preliminary design and then the design was detailed and standardized. After that, various parts were fabricated using 3D printer and then each of them was tested and modified whenever necessary. Currently, the hand is in its fourth version.

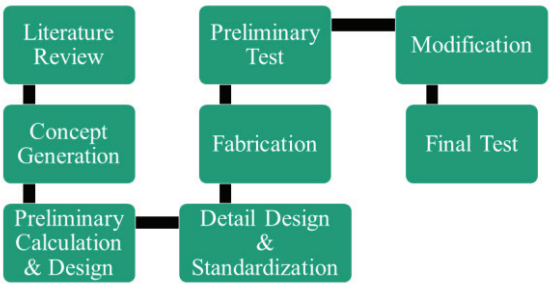

Fig 3. Methodology

Materials used for the fabrication of hand are shown in table 1.

TABLE I. LIST OF MATERIALS USED

S.N	Name	Specification	Quantity
1	Bluetooth Module	HC-06	1 pc
2	Battery	Li-Po, 12V, 2000 mAh	1 pc
3	Arduino	Uno	1 pc
4	3D Printing Filament	PLA	1 Kg
5	Motor	Micro Servo, 5V, SG90, 1.8 kg-cm Torque	5 pc
6	Motor Driver	L293D Module	3 pc
7	Nuts and Bolts	M5	6 pc
		M2	20 pc

Fig 4. Finger Linkage Mechanism prototype wooden (left) and 3D printed (right)

Fig 5. First 3D printed prototype of the lower palm and fingers: side view (left) and front view (right)

Fig 6. 3D printed prototype of prosthetic hand showing pinch operation (left) and backside view (right)

Fig 7. KU hand Version 4.0

III. RESULTS AND DISCUSSION

This prosthetic hand performs four basic operations: fist mode, full open, pinch (shown in fig. 7) and thumb lateral hold. Using these operations, the prototype hand is able to perform tasks such as gripping bottles, books and materials of diameter or thickness less than 8 cm, pinching powdery substances like salt and sugar, carrying heavy objects having handles and weighing not more than 30 kg and holding keys and small cards. The KU hand version 4.0 has a delay time of about 2 to 3 seconds.

IV. CONCLUSION

KU Hand V4.0, a motorized prosthetic hand prototype for below elbow amputee is designed and fabricated. Individual fingers in the hand are motorized and can be controlled using an application in smart phone. Complete hand is fabricated using 3D printer and locally available materials.

V. RECOMMENDATION

The motor used for actuation had very low revolutions per minute (RPM) resulting in slower movement of fingers and it is recommended to use an actuator with higher RPM and similar torque for a faster movement. Also, there is no feedback mechanism in for the device, so it is recommended to use potentiometers or similar components to accept feedback for improving the performance in the future. It is also recommended to use nut bolts of lesser diameter than used in the hand.

ACKNOWLEDGMENT

This project was supported in part by Institute for Social and Environmental Transition – Nepal (ISET-Nepal), Chakupat, Lalitpur, Nepal under 'Abishkar Fellowship'. 3D printing work would not have been successful without the support of Design Lab, Kathmandu University.

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