

Development Of An Affordable And Functional Upper Limb Prosthetic Terminal Device For Partial Hand Amputees

Shweta M¹, Ifra Fatima², Eram Kauser Zerdi³, Esha Mahek⁴

¹Assistant Professor, Department of Computer Science and Engineering, Faculty of Engineering and Technology(exclusively for women), Sharnbasva University, Kalaburagi, India.

^{2, 3, 4}Student, Department of Computer Science and Engineering, Faculty of Engineering and Technology(exclusively for women), Sharnbasva University, Kalaburagi, India.

ABSTRACT

Over the past decade, significant papers have shown that rehabilitation exercise is efficient in enhancing Parkinson's disease efficiency. However, the previous devices in Parkinson Disease Rehabilitation are not very efficient as they are far too complicated, heavy in size, and difficult to conduct. This paper will focus on developing a smart rehabilitation hand device prototype using an Arduino microcontroller, to control the soft actuator by using pneumatic system and IOT system for the individual with Parkinson's disease. The actuators are designed mechanically to match and support the human finger range as it features a lightweight structure, simplistic design, cost-effective and safer to use compared to other conventional actuators. A soft actuator, accelerometer sensor, pneumatic air valve and Arduino Mega were designed as a control hardware system to operate the smart rehabilitation glove. Therefore, this study will focus on obtaining data results based on the length of the single actuator, the bending angle of the actuator based on the applied pressure, the hand position of the accelerometer sensor based on the x, y, z-axis and the suitable pressure for the SGRD rehabilitation system for future research purposes. This prototype will assist the subject's hand movement by improving the subject quality in helping the patient with Parkinson's disorder recover.

Keywords: Prosthetic terminal device, 3D printed, CAD

1.INTRODUCTION

According to the Centers for Disease Control and Prevention, each year about 1500 US babies are born with upper limb deficiencies.¹ Limb deficiencies are either longitudinal or transverse.² Longitudinal deficiencies are along the long axis of the limb (complete or partial absence of the radius, ulna, fibula, or tibia), and mostly genetic or teratogenic in origin.² In a transverse deficiency, all of the elements below a certain level in the patient's arm are missing (loss of forearm, hand) and the limb structures before the point of the defect remain intact.¹ The congenital amputation for a transverse deficiency is named after the segment where there is no remaining skeletal structure. The molecular pathogenesis of the transversal growth arrest of the limb is thought to be related to disruptive events affecting the apical ectodermal ridge after limb buds form.³ On rare occasions, teratogenic factors such as tobacco, cocaine, and alcohol may be responsible for the pathogenesis if one limb is involved.³ Nearly 50% of the children with transverse reduction deficiencies wear a prosthetic device to enhance the ability to perform functional activities.² The current literature lacks clear evidence as to whether prosthetic treatment is superior to prosthetic non-usage.³

In a recent study, "Congenital upper limb deficiency: a case report," a newborn, with a transverse radial congenital amputee was followed through his first year of life.⁴ It was reported that he received physical therapy (PT) and occupational therapy (OT) continually since he was 3 months old. It was proven that early intervention and multidisciplinary collaboration of treatment were vital for the child's progress. Increased acceptance was also shown with the use of a prosthetic device that was introduced at 6 months of age. This management of a patient starting at a young age with multidisciplinary approaches encouraged the child to meet all developmental milestones with functional and sensory components of integration.⁴

Although 3D printing has been around for many years, it has recently become a more attainable and accessible commodity thanks to consumer-friendly prices and advances in the technology. The introduction of 3D printing for the manufacturing of prostheses has resulted in the development of new cost reduction strategies and better accessibility and customization of prosthetic designs.⁵ Some advantages of 3D-printed hands include being built from one part and, requiring no assembly, more freedom with larger geometries allowed, customized designs, and rapid design improvements secondary to lower costs related to modifications.⁶

Previous investigations reported increased hand function, strength, and range of motion after the use of traditional hand prosthesis. Zuniga et al compared the coactivation of the muscles surrounding the joint before and 6 months following the use of a wrist-driven 3D prosthetic.⁷ The study concluded that the use of a wrist-driven 3D-printed hand prosthesis lowered the coactivation index by 70% in children with congenital upper limb reduction deficiencies. The reduction in coactivation and possible improvement in motor control strategies can potentially improve prosthetic rehabilitation outcomes.⁶ Currently, there is limited research on protocols specific to rehabilitation with the use of 3D-printed prosthetics

Purpose

The purpose of this case report was to evaluate the outcomes of utilizing a 3D prosthetic device with a home exercise program. This case study was intended to determine if the application of a home exercise program utilizing a 3D-printed prosthetic hand resulted in increased range of motion, strength, coordination, sensory integration, and perceived function of the upper extremity. Consent was obtained from the child's guardian and assent was given from the child.

The merits of our Research:

1. It helps the people who have lost one of their hands or if it is paralysed.
2. Low cost. The whole work can be completed under 15,000 rupees, which makes the robotic hand very affordable in comparisons to its present contemporary robotic hand proposal.
3. Very easily portable. It is easy to carry the hand around.
4. Light weight 3D printed modules/parts, makes it very easy for the amputees to carry it around with them.
5. Has a lot of scope for modification. Its working can be made completely automatic and wireless. It can be controlled through cloud or wifi.

II. PROSTHETIC HAND DESIGN

Materials and Procedures

The hand is designed using SolidWorks Computer Aided Design (CAD) software. SolidWorks is utilized because of easy to use and operate. The solid model of prosthetic hand design can be exported into SimMechanics model for 3D animation and kinematics analysis purposes. The 3D CAD model of the prosthetic hand cover can be seen in Fig. 1. In order to the proposed prosthetic hand has the same size and weight with the natural human hand, all of mechatronics components have been designed to fit into the hand.

After the 3D model is developed in SolidWorks, the model needs to be printed using 3D printer. The hand is made from PLA (Polylactic Acid) material. The material is selected due to lightweight property. The 3D hand model of this prosthetic hand is inspired by Ada Hand from Open Bionics.

The size of the prosthetic hand is 180 mm in length, 85 mm in width, and 50 mm in thick. The overall mass of the prosthetic hand is 261 grams. The size, shape, and weight of the prosthetic hand approach with the human natural hand. This is very lightweight prosthetic hand, when the user/transradial amputee used it as prosthetic hand, the user can manipulate object grasping task without feels fatigue. The general characteristics comparison of AstoHand v1.0 can be summarized in Table 2. Based on the Table II, the mass of available robotic hand varies from 261 gr to 760 gr.

Robotic Arm:



Computer-Aided Design (CAD)

Computer-aided design software or **CAD software** refers to a type of software program used by designers and engineers to create two-dimensional and three-dimensional models of physical components. CAD software has all but replaced the t-squares and protractors used by the designers of yesterday in a process known as **manual drafting**, the traditional 'pencil on paper' approach to engineering and design.

Two-Dimensional CAD

2D CAD models are what most of us are familiar with. These models are flat, two-dimensional drawings that provide overall dimensions, layouts, and information needed to reproduce or build the subject. Examples of these types of drawings are found in a variety of industries including aerospace, architecture, automotive, cartography, civil engineering, interior design, landscaping, and even fashion.

If you have ever built a house, you probably haven't forgotten the small fortune you had to fork over for your floor plans. The architect you purchased them from almost certainly used CAD to create them. This photo shows a two-dimensional floor plan drawn with CAD software. It looks messy, but this one image contains most of the information that a builder would need to construct the inside of this house.

Three-Dimensional CAD

3D CAD models have uses similar to those of 2D CAD models. Then why the distinction? A three-dimensional CAD model provides greater detail about the individual components and assemblies of a physical object. In other words, 3D models show you how something fits together and operates rather than just how big it is and its overall shape. There isn't a great need for 3D modeling when it comes to floor plans, but what about the world of mechanics? The intricate pieces used in the automotive or manufacturing industries, for instance, might be best represented by a 3D model such as this one.

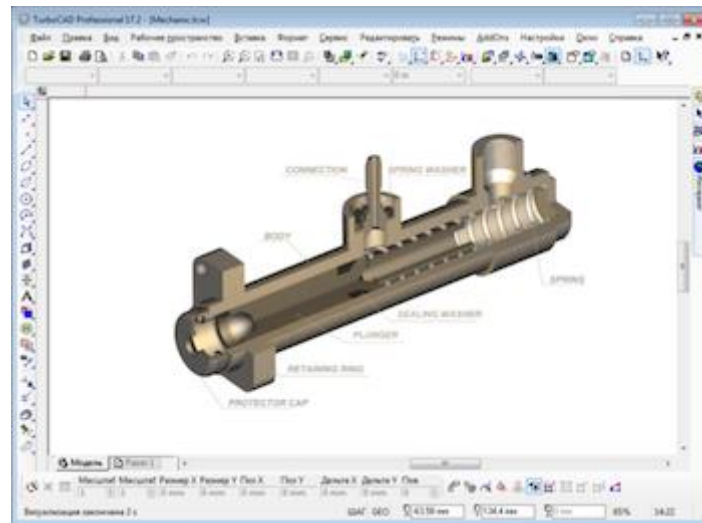


Fig. 3D mechanical Drawing

3D CAD Modeling Methods

Each of the above 3D CAD programs utilizes a different method for modeling.

Solid Modelling

1. Parametric Modelling: a type of solid modelling that uses 2D sketches to create features and objects that are modifiable with a feature history tree. Features are located and manipulated using geometric and functional relationships with other sketches, features and objects.

2. Direct Modelling: like parametric modelling, direct modeling uses sketches to create 3D features based on relationships with existing geometry. However, there is no history tree, and the original sketch is absorbed into the feature and future edits are made on the resulting geometry.

- **Surface Modelling**

Another type of modelling that relies on surfaces to generate geometry. Surface modelling can be both parametric (based on geometric and functional relationships) or freeform. Freeform surface modelling is used to manipulate the surface of the model similar to how someone would model with clay.

- **Code-driven modelling**

This is a growing area of modelling where geometry is generated autonomously based on conditions set in place by the designer. This type of modelling is excellent for 3D printing as it can be used to generate 3D structures that can't be manufactured through any other means.

This is the Robotic hand's frame. It can be made from a lot of things like wood, plastic, metal, etc. It is the part that drives the main motive of the project. A 3D printed frame is the most suitable for this paper since it is easy to make, light weight and cheap. Almost any design specification can be met using 3D printing techniques.

1. Other than these main components we need jumper wires for connections.
2. We need a bread board for converging all the connections into one place.
3. A 7.4v 2200 mAh Lithium-Polymer battery to power the servo motors and 9v Nickel- Cadmium battery for powering the ARDUINO.
4. Fishing nylon wires for the movements of the hand frame.

The servo motor is a linear actuator. There are two types of servo motors, one which rotates 360° and is continuous and, another one which has a 180° rotation and is non continuous.

The problem with continuous motor is that it does not move in the backward direction, it is always clockwise or anticlockwise. This is a drawback as the fingers move both front and back. Hence we chose the 180° , non-continuous motor.

WHY ROBOTIC ARM?

There are many situations where humans just can't just get their hands onto something. There are numerous situations when humans can't directly involve themselves. Situations like working in canyons, caves, mining, works involving minute details like manufacture of watches, automobile parts, etc. The robotic arm has its applications not just in fields where things get smaller.

It has huge applications in large industries, where a lot of manpower is needed. The robotic arm has great use when it comes to precision and monotonicity.

The research of robotic hand has grown significantly especially in the development of robotic prosthetic hand ranging from research hand to commercial hand. The available prosthetic hand in the market with great features is very expensive that make it only certain people can buy it.

The purpose of this research is to develop a low cost prosthetic hand using widely used mechatronics components. The hand must be easy to manufacture, and easy to maintain with the available component in the market. The prosthetic hand also must be able to perform activities of daily living (ADLs) such as take, grasp, and hold an object.

Some researches about prosthetic hand significantly increased in the size, weight, and anthropomorphism. The prosthetic hand is used to replace the lost hand especially for transradial amputation. In order to the prosthetic hand can move using command from the remaining muscle of the amputee, the hand must read the muscle activities by using sensor. The most widely used sensor for reading the muscle activities is electromyography (EMG) sensor. Some research hands use pattern recognition method of the EMG signal to distinguish the hand movement or gesture. One of common pattern recognition method in the EMG signal recognition is neural network [1, 2]. This method is difficult to implement in the prosthetic hand control system due to the limitation of hardware memory in the microcontroller. The simple control algorithm is developed in this research using the user keypad & servo motors to drive several grip pattern of prosthetic hand.

Some open source hand is available today to reduce the cost and to increase manufacturability. Open source prosthetic hand based on 3D print are widely used Ada Hand [3] from Open Bionics and Dextrus [4] from Open Hand Project. The state of the art prosthetic hands commercially available are Vincent Hand [5], Michelangelo [6], Bebionic [7], and iLimb [8]. They have great performance in ADLs especially for object grasping manipulation but they are still very expensive.

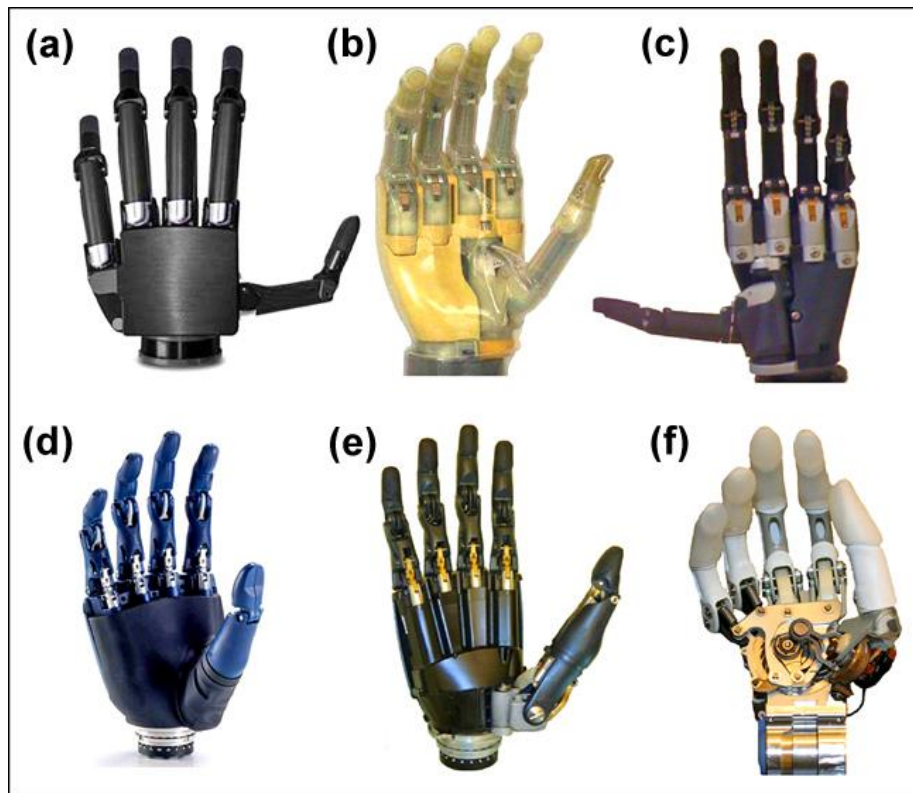
In this paper, the research goal is try to develop an affordable five degree of freedom (DOF) robotic prosthetic hand and two joints in each finger. For performing the activities of daily living (ADLs), the hand is designed with seven grip patterns, using widely used low cost servo motor incorporating tendon-spring mechanism. The proposed of the prosthetic hand must be able to grasping task with various objects and perform activities of daily living (ADLs). Based on the ref [9], the most used grasping pattern is power grip followed by precision grip. The prosthetic hand is designed with seven grip patterns to perform object grasping manipulation.

The prosthetic hand has been implemented and being used in various countries of the world. The most widespread use of the prosthetic hand is in major countries like the United States of America, China, Russia, etc. The use of the prosthetic hand is limited to developed and prosperous countries as, the prosthetic hand is usually very expensive since it is sophisticated. Technology has advanced so much that there are brain controlled hands which use brain waves. Others use voice and text inputs.

Published Specifications of Commercial Hands

The six hands shown in represent the latest developments in commercial myoelectric hands. While the iLimb (Touch Bionics; Livingston, United Kingdom) and Bebionic (RSL Steeper; Leeds, United Kingdom) hands have received much media attention, the Vincent (Vincent Systems; Weingarten, Germany) and Michelangelo (Otto

Bock; Duderstadt, Germany) hands are just becoming available to the public. Therefore, published information on the Vincent and Michelangelo hands is limited.



(a) Vincent hand by Vincent Systems, **(b)** iLimb hand by Touch Bionics, **(c)** iLimb Pulse by Touch Bionics, **(d)** Bebionic hand by RSL Steeper, **(e)** Bebionic hand v2 by RSL Steeper, and **(f)** Michelangelo hand by Otto Bock. All hands shown without cosmetic glove.

III. BLUETOOTH PROFILE

Bluetooth is low cost, low power short-range radio technology originally developed as a cable replacement to connect devices such as mobile phone handsets, headsets and portable computers. No longer do people need to connect, plug into, install, enable or configure anything to anything else.

The Bluetooth specification is an open, global specification defining the complete system from the radio right up to the application level. Version 1.0 of the Bluetooth came into existence in 1994 when Ericsson Mobile Communication began its study for alternatives to replace the cable and this technology hit the market in 1999. This study concluded with radio link as a better option than the optical communication like infrared because of its line of sight limitation.

It is not possible to get universal acceptance for a new technology developed by a single company particularly for blue tooth. Because numerous corporations are designing and producing vast range of telecom gadgets.

Then they formed Bluetooth Special Interest Group(SIG) to define and promote Bluetooth specification with five key promoters:

- ❖ Ericsson Mobile Communications
- ❖ Intel Corp.
- ❖ IBM Corp.

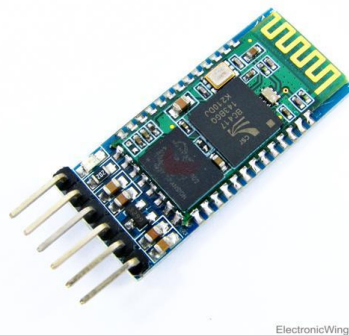
- ❖ Toshiba Corp.
- ❖ Nokia Mobile Phones

Bluetooth devices operate at 2.4 GHz globally available license free band. This band is reserved for general purpose usage of Industrial, Scientific and Medical applications. Thus Bluetooth has to be very robust because many users, polluters of this shared spectrum.

Bluetooth is mainly designed for low power radio frequency link available in the range of 10m, 20m and 100m. Bluetooth specification allows three different powers they are referred as three classes of Bluetooth devices.

Bluetooth devices can operate in two modes for data transfer using Bluetooth devices one has to act as Master and other as Slave. It is the Master which initiates the transaction, establishes the link with slave. Most importantly Master decides the Frequency Hopping Spectrum, which Slave has to follow. One Master can have maximum seven slaves thus it has to decide seven different Frequency Hopping Spectrums.

HC 05 Bluetooth Module:



HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup.

Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Bluecore 04-External single chip Bluetooth system with CMOS technology and with AFH(Adaptive Frequency Hopping Feature). It has the footprint as small as 12.7mmx27mm. Hope it will simplify your overall design/development cycle.



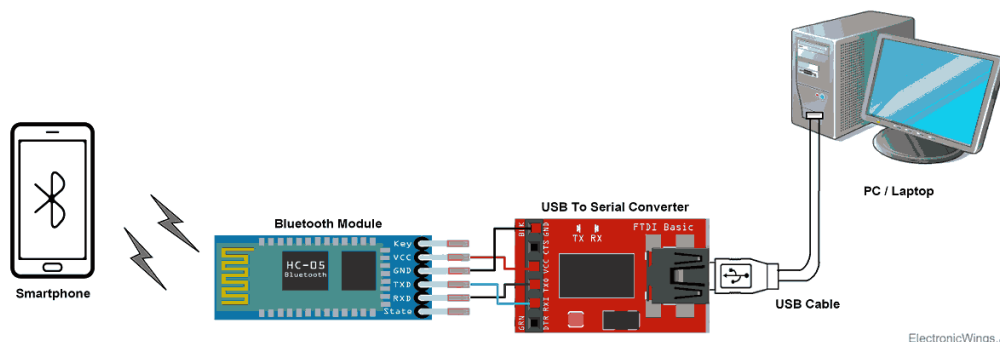
Bluetooth serial modules allow all serial enabled devices to communicate with each other using Bluetooth.

It has 6 pins

Bluetooth communication between Devices

E.g. Send data from Smartphone terminal to HC-05 Bluetooth module and see this data on PC serial terminal and vice versa.

To communicate smartphone with HC-05 Bluetooth module, smartphone requires Bluetooth terminal application for transmitting and receiving data. You can find Bluetooth terminal applications for android and windows in respective app. store.



Bluetooth Module Serial Interface

So, when we want to communicate through smartphone with HC-05 Bluetooth module, connect this HC-05 module to the PC via serial to USB converter.

Before establishing communication between two Bluetooth devices, 1st we need to pair HC-05 module to smartphone for communication.

LCD 16 X 2:

Basics of LCD

► DDRAM - Display Data RAM

Display data RAM (DDRAM) stores display data represented in 8-bit character codes. Its extended capacity is 80 X 8 bits, or 80 characters. The area in display data RAM (DDRAM) that is not used for display can be used as general data RAM. So whatever you send on the DDRAM is actually displayed on the LCD. For LCDs like 1x16, only 16 characters are visible, so whatever you write after 16 chars is written in DDRAM but is not visible to the user.

Figures below will show you the DDRAM addresses of 1 Line, 2 Line and 4 Line LCDs.

00	01	02	03	04	05	06	07	...	32	33	34	35	36	37	38	39	← Character position (dec.)
00	01	02	03	04	05	06	07	...	20	21	22	23	24	25	26	27	← Row0 DDRAM address (hex)

Figure : DDRAM Address for 1 Line LCD

00	01	02	03	04	05	06	07	...	32	33	34	35	36	37	38	39	← Character position (dec.)
00	01	02	03	04	05	06	07	...	20	21	22	23	24	25	26	27	← Row0 DDRAM address (hex)
40	41	42	43	44	45	46	47	...	60	61	62	63	64	65	66	67	← Row1 DDRAM address (hex)

Figure : DDRAM Address for 2 Line LCD

00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	10	11	12	13	...	32	33	34	35	36	37	38	39	← Character position (dec.)
00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	10	11	12	13	...	20	21	22	23	24	25	26	27	← Row0 DDRAM address (hex)
40	41	42	43	44	45	46	47	48	49	4A	4B	4C	4D	4E	4F	50	51	52	53	...	60	61	62	63	64	65	66	67	← Row1 DDRAM address (hex)
14	15	16	17	18	19	1A	1B	1C	1D	1E	1F	20	21	22	23	24	25	26	27	...	32	33	34	35	36	37	38	39	← Row2 DDRAM address (hex)
54	55	56	57	58	59	5A	5B	5C	5D	5E	5F	60	61	62	63	64	65	66	67	...	70	71	72	73	74	75	76	77	← Row3 DDRAM address (hex)

Figure : DDRAM Address for 4 Line LCD

IV. SERVO MOTOR

Types of Servo Motor

Servo motors are classified into different types based on their application, such as AC servo motor, DC servo motor, brushless DC servo motor, positional rotation, continuous rotation and linear servo motor etc. Typical servo motors comprise of three wires namely, power control and ground. The shape and size of these motors depend on their applications. RC servo motor is the most common type of servo motor used in hobby applications, robotics due to their simplicity, affordability and reliability of control by microprocessors.

DC Servo Motor

The motor which is used as a DC servo motor generally have a separate DC source in the field of winding & armature winding. The control can be achieved either by controlling the armature current or field current. Field control includes some particular advantages over armature control. In the same way armature control includes some advantages over field control. Based on the applications the control should be applied to the DC servo motor. DC servo motor provides very accurate and also fast respond to start or stop command signals due to the low armature inductive reactance. DC servo motors are used in similar equipments and computerized numerically controlled machines.



AC Servo Motor

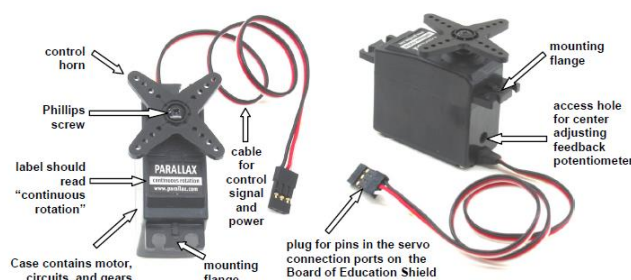
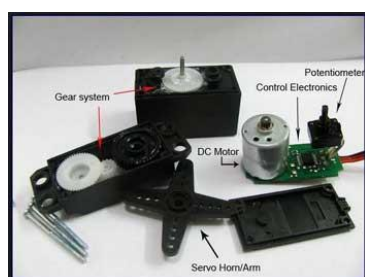
AC servo motor is an AC motor that includes encoder is used with controllers for giving closed loop control and feedback. This motor can be placed to high accuracy and also controlled precisely as compulsory for the applications. Frequently these motors have higher designs of tolerance or better bearings and some simple designs also use higher voltages in order to accomplish greater torque. Applications of an AC motormainly involve in automation, robotics, CNC machinery, and other applications a high level of precision and needful versatility.



AC Servo Motor

Positional Rotation Servo Motor

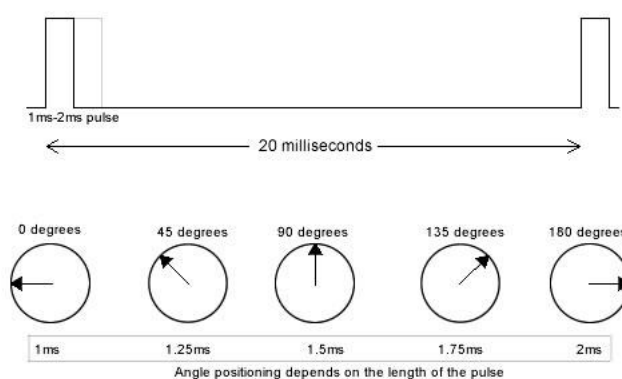
Positional rotation servo motor is a most common type of servo motor. The shaft's o/p rotates in about 180°. It includes physical stops located in the gear mechanism to stop turning outside these limits to guard the rotation sensor. These common servos involve in radio controlled water, radio controlled cars, aircraft, robots, toys and many other applications.



Servo Motor Working (Positional Rotation):

Servo motors (or servos) are self-contained electric devices that rotate or push parts of a machine with great precision. By rotating a shaft connected to the engine throttle, a servo regulates the speed of a fuel-powered car or aircraft. Servos also appear behind the scenes in devices we use every day. The servo motor is actually an assembly of four things: a normal DC motor, a gear reduction unit, a position-sensing device (usually a potentiometer—a volume control knob), and a control circuit.

The function of the servo is to receive a control signal that represents a desired output position of the servo shaft, and apply power to its DC motor until its shaft turns to that position. It uses the position-sensing device to determine the rotational position of the shaft, so it knows which way the motor must turn to move the shaft to the commanded position. The shaft typically does not rotate freely round and round like a DC motor, but rather can only turn 200 degrees or so back and forth. The servo has a 3 wire connection: power, ground, and control. The power source must be constantly applied; the servo has its own drive electronics that draw current from the power lead to drive the motor.



The control signal is pulse width modulated (PWM), but here the duration of the positive-going pulse determines the position of the servo shaft. For instance, a 1.520 millisecond pulse is the center position for a Futaba S148 servo. A longer pulse makes the servo turn to a clockwise-from-center position, and a shorter pulse makes the servo turn to a counter-clockwise-from-center position.

The servo control pulse is repeated every 20 milliseconds. In essence, every 20 milliseconds you are telling the servo, “go here.” To recap, there are two important differences between the control pulse of the servo motor versus the DC motor. First, on the servo motor, duty cycle (on-time vs. off-time) has no meaning whatsoever—all that matter is the absolute duration of the positive-going pulse, which corresponds to a commanded output position of the servo shaft. Second, the servo has its own power electronics, so very little power flows over the control signal. All power is drawn from its power lead, which must be simply hooked up to a high-current source of 5 volts.

Contrast this to the DC motor. On the Handy Board, there are specific motor driver circuits for four DC motors. Remember, a DC motor is like a light bulb; it has no electronics of its own and it requires a large amount of drive current to be supplied to it. This is the function of the L293D chips on the Handy Board, to act as large current switches for operating DC motors. Plans and software drivers are given to operate two servo motors from the HB. This is done simply by taking spare digital outputs, which are used to generate the precise timing waveform that the servo uses as a control input. Very little current flows over these servo control signals, because the servo has its own internal drive electronics for running its built-in motors.

Sealed maintenance free battery:

Battery (electricity), an array of electrochemical cells for electricity storage, either individually linked or individually linked and housed in a single unit. An electrical battery is a combination of one or more electrochemical cells, used to convert stored chemical energy into electrical energy. Batteries may be used once and discarded, or recharged for years as in standby power applications. Miniature cells are used to power devices such as hearing aids and wristwatches; larger batteries provide standby power for telephone exchanges or computer data centers.



Figure : SMF Battery

SMF battery which means Sealed Maintenance Free battery are sealed completely because there is no need to add water. The electrolyte used is in the form of gel which fills the cavity of plates. Just like other batteries, it also emit H₂ and O₂ gases and due to sealed batteries both these gases combine to form water.

SMF batteries measure created in an eco-friendly, ISO Certified & trendy plant with a huge producing capability and square measure being sold-out worldwide. There are differences between SMF batteries and other tubular batteries. In SMF Batteries no distilled water or effort is needed and requires only a . There are a wide selection of SMF battery on the market to suit all applications of standby power needs like UPS, electrical converter and Emergency Lights, communication system, hearth Alarm & Security Systems, Railway communication, Electronic group action and money Registers, star Lanterns and Systems, etc. The SMF batteries are available industrial plant charged conditions and have a high period thereby requiring longer time intervals between recharging of batteries available. As we are one of the leading SMF battery manufacturers, we provide the genuine and products that tops in six stigmatic tests.

Lithium (Li) Battery:

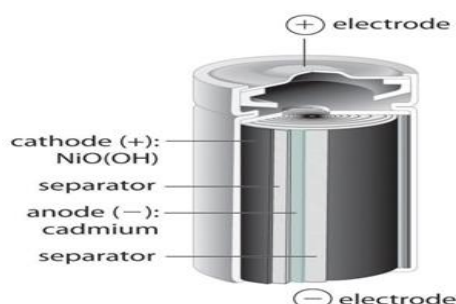
We all use it in portable devices such as cell phone, a laptop computer or a power tool. The lithium battery has been one of the greatest achievements in portable power in the last decade; with use of lithium batteries we have been able to shift from black and white mobile to color mobiles with additional features like GPS, email alerts etc. These are the high energy density potential devices for higher capacities. And relatively low self-discharge batteries. Also Special cells can provide very high current to applications such as power tools.



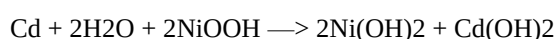
Li Battery

Nickel Cadmium (Nid) Battery:

The Nickel Cadmium batteries have the advantage of being recharged many times and possess a relatively constant potential during discharge and have more electrical and physical withstanding capacity. This battery uses nickel oxide for cathode, a cadmium compound for anode and potassium hydroxide solution as its electrolyte.

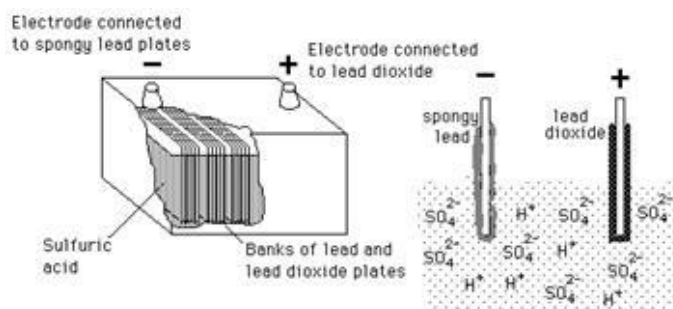


When the battery is charged, the chemical composition of the cathode is transformed and the nickel hydroxide changes to NIOOH. In the anode, formation of Cadmium ions take place from Cadmium Hydroxide. When battery is discharged, the cadmium reacts with NiOOH to form back nickel hydroxide and Cadmium Hydroxide.



Lead Acid Battery:

Lead Acid batteries are widely used in automobiles, inverters, backup power systems etc. Unlike tubular and maintenance free batteries, Lead Acid batteries require proper care and maintenance to prolong its life. The Lead Acid battery consists of a series of plates kept immersed in sulphuric acid solution. The plates have grids on which the active material is attached. The plates are divided into positive and negative plates. The positive plates hold pure lead as the active material while lead oxide is attached on the negative plates.



Lead Acid Battery

A completely charged battery can discharge its current when connected to a load. During the process of discharge, the sulphuric acid combines with the active materials on the positive and negative plates resulting in the formation of Lead sulphate. Water is the single most important step in maintaining a Lead Acid battery. The frequency of water depends on usage, charge method and operating temperature. During process, the hydrogen atoms from the sulphuric acid react with oxygen to form water.

This results in the release of electrons from the positive plates which will be accepted by the negative plates. This leads to the formation of an electric potential across the battery. The electrolyte in the Lead Acid battery is a mixture of Sulphuric acid and water which has a specific gravity. Specific gravity is the weight of the acid-water mixture compared to equal volume of water. The specific gravity of pure ions free water is 1.

The lead-acid batteries provide the best value for power and energy per kilowatt-hour; have the longest life cycle and a large environmental advantage in that they are recycled at an extraordinarily high rate. No other chemistry can touch the infrastructure that exists for collecting, transporting and recycling lead-acid batteries.

Along with this article, Lithium ion battery is discussed with its advantages and disadvantages.

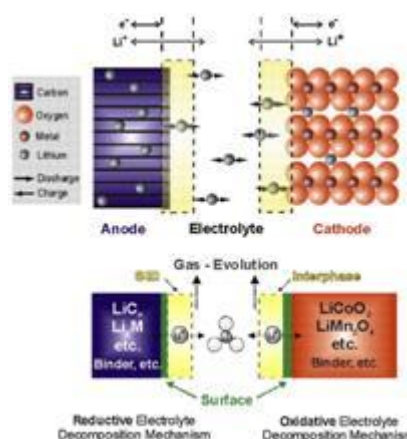
Working of Lithium – Ion Battery



Lithium –Ion batteries are now popular in majority of electronic portable devices like Mobile phone, Laptop, Digital Camera, etc due to their long lasting power efficiency. These are the most popular rechargeable batteries with advantages like best energy density, negligible charge loss and no memory effect. Li-Ion battery uses Lithium ions as the charge carriers which move from the negative electrode to the positive electrode during discharge and back when charging. During charging, the external current from the charger applies an over voltage than that in the battery. This forces the current to pass in the reverse direction from the positive to the negative electrode where the lithium ions get embedded in the porous electrode material through a process called Intercalation.

The Li- Ions pass through the non aqueous electrolyte and a separator diaphragm. The electrode material is intercalated lithium compound.

The negative electrode of the Li-Ion battery is made up of carbon and the positive electrode is a metal oxide. The most commonly used material in the negative electrode is Graphite while that in the positive electrode may be Lithium cobalt oxide, Lithium ion phosphate or Lithium manganese oxide. Lithium salt in an organic solvent is used as the electrolyte. The electrolyte is typically a mixture of organic carbonates like Ethylene carbonate or Diethyl carbonate containing lithium ions. The electrolyte uses anion salts like Lithium hexa fluoro phosphate, Lithium hexa fluoro arsenate monohydrate, Lithium per chlorate, Lithium hexa fluoro borate etc. Depending upon the salt used, the voltage, capacity and life of the battery varies. Pure lithium reacts with water vigorously to form lithium hydroxide and hydrogen ions. So the electrolyte used is non aqueous organic solvent. The electrochemical role of the electrodes charge between anode and cathode depends on the direction of current flow.



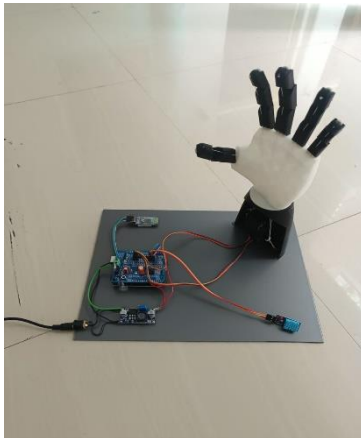
Li Ion Battery Reaction

In the Li-Ion battery, both the electrodes can accept and release lithium ions. During the Intercalation process, the lithium ions move into the electrode. During the reverse process called de intercalation, the lithium ions move back. During discharging, the positive lithium ions will be extracted from the negative electrodes and inserted into the positive electrode. During the charging process, the reverse movement of lithium ions takes place.

Results:

A microcontroller based bionic hand using Bluetooth module, 3D printed Arduino-based bionic arm can give a savvy and adaptable answer for people with upper appendage removals. The utilization of 3D printing innovation considers the production of prosthetic parts that are custom fitted to a singular's particular requirements and inclinations, while the Arduino microcontroller gives exact control and criticism to the arm's developments. Additionally, the open-source nature of both 3D printing and Arduino programming means that this technology can continue to evolve and improve as more people contribute their ideas and expertise. While there are still challenges to be addressed in terms of improving the durability and functionality of these prosthetics, the potential benefits of this technology are significant, particularly for those who may not have had access to affordable prosthetic solutions in the past.

Each finger managed to contract individually, however some fingers performed same as others. An example of a digit with worse performance was the thumb on the robotic hand.



Figures 1 and 2 shows the imitation of the all fingers close & open movement was successful. As for the hand signs the robotic hand was able to replicate the hand signs carried out by the operator with the mobile app. Grip test of the robotic hand concluded that only objects with some give in them, that is to say soft to semi-soft objects, could be grasped. Objects of various shapes could be grasped but items of oblong cylindrical nature were the easiest to grip followed by lightweight spherical and rectangular objects last.

Overall, the development of a 3D printed Arduino-based bionic hand is an exciting area of research that has the potential to improve the lives of individuals with limb differences. However, it is important to approach this work with caution and to carefully consider the safety and efficacy of the device.

V. CONCLUSIONS

This rehabilitation protocol was proposed to investigate the effectiveness of exercise utilizing a 3D-printed prosthetic. Utilizing the 3D hand during the specific activities of the protocol helped increase functional mobility to increase usage of the 3D hand in the future. With the increased accessibility and attainability of 3D printing technology, the cost-effectiveness of the technology allowed for a feasible design. There was no cost to the research subject and family.

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