DESIGN OF VOICE AND FLEX OPERATED EXOSKELETON ARM FOR PARALYZED PEOPLE

N. NAGA SURESH BABU Sr. Assistant Professor, School of Mechanical Engineering REVA University, Bangalore, nagasureshbabu@reva.edu.in
Prof. K. Venkata Subbaiah, Professor, HOD Andhra University, Vishakhapatnam
Dr Mallikarjun Koripadu, Director - BPM Consulting, Lab crop Drug Development Bengaluru, Karnataka, India
AMIT RAVI SASTRY , ADARSH K SHETTY, ANIKETH M, ANUSH SADANANDA KOTIAN,
School of Mechanical Engineering, REVA University

Abstract
Exoskeleton arm is a device which helps paralyzed to move his injured arm for recovery of full range of motion. Exoskeletons are wearable robotic devices that have the aim of power assisting the hand with voice and flex assisted features. Most of the exoskeleton arms available in the market are only of flex assisted or either voice assisted, the combined features of voice and flex enabled is easy for operation of the patients. The objective of this work is to design and fabricate the exoskeleton arm in a way that it incorporates maximum number of assistance features and is made feasible, the exoskeleton is equipped arm both flex and voice sensor. Initially each part of the exoskeleton arm is drafted according to design calculations in the CATIA V5 application, then the model was tested for failures and stress points in CATIA and then, every part is later assembled and therefore the final 3d product is obtained. The final model is constructed, tested, and analyzed for many conditions like different weights in hand and different voices. The scope of the future work is that the model can be made lighter and more robust by using lightweight motor and a lightweight frame. The result obtained from this model are that, the model was tested for different weights and different voice commands which the model successfully passed in all the above mentioned tests.

Keywords: Exoskeleton, Power-Assist, CATIA V5 and Sensors.

Introduction

Exoskeleton arm is a mechanical structure which adds power from mechanical motor to human arms giving it various benefits such as in medical, military and load carrying jobs. Few companies have already implemented the use of exoskeleton systems for the labours having lifting duties. This method or technology can also be used in medical field as in physiotherapy sessions.

The existing exoskeleton arm are available with fewer degree of freedom compared to the normal human arm which might be burdensome but the physiotherapy session the patient requires only specific moments to be performed for the recovery.

Factor to be considered is the weight of the frames of prosthetics which must be reduced. It is overcome by using motors instead of actuators making it more practical to use. By installing microcontroller, we can add many new features such as sensors and voice recognition making it appropriate control source. The controls for motion are not related to the actions of a normal person which cause the corresponding motion of arm. For example, flexion of the "arm" of prosthetic arm may cause different movement from the shoulder whereas in a normal person elbow and shoulder motions are independent. The result of this is that an entirely new pattern of activity should be learnt in order to make the exoskeleton arm useful., and ultimate performance is limited because the degree of freedom which is required are few, and the constraints of the control system are too many

The medical field would be going to be the major area for the exoskeleton technology, where it can be used for enhanced precision during surgery or as an assist to nurses to move heavy patients.

For people who are severely injured but not completely paralyzed, there's every reason to They're likely to improve even more. This technology would expand the clinical toolbox available for people with spinal cord injury and other diseases.

It's very hard for paralyzed patient to do any kind of moment. Even if they aren't able recover from it. The exoskeleton arm will be perfect aid for those patients making them independent and able to make a movement or undergo self-physiotherapy.
In this paper, several research papers have been reviewed to study the case of the exoskeleton arm and the technology used before. Through the papers problem statement was defined and objectives

Several design calculations were done along with few parameters that had to be considered for the exoskeleton arm to work in a safer way. To go after the calculation 2D and 3D along with analysis was done to check the material under varying loads.

Fabrications of the model and installation requirements for the flex and voice module following up with the specific codes for the components are done. Testing is crucial part for product to work. Test like voice and weight testing are undergone to the functionality of the model

Statement of the Problem

The existing exoskeleton models operate on actuators which are quite bulky and expensive. Hence in this paper, power assist type exoskeleton has been selected rather than a more expensive power amplification device. The problem of weight of the previous exoskeleton arms were addressed by adding simple stepper motor and simple structural elements. The cost required to design and manufacture of device are greatly reduced by incorporating simple sensors and light weighted structures are

Objectives of the study

- To develop a prototype model of FLEX AND VOICE controlled exoskeleton arm.
- To reduce human effort for extension of arm.
- To reduce the size and weight of the device to prevent the fatigue of the user & to preserve the comfort of the user and to prevent any injuries or discomfort.

Review of Literature

An overview of several papers previously done on this topic before. These papers were selected based on the work carried out in development of exoskeleton arm. Vast research was done on the following topic, the following few relevant papers have been presented over here to understand the statement of the problem. The following literature review is just a brief explanation of the work carried out by the authors and the flaws have been listed accordingly. This helps in a finding out the issues which could be set as objectives for the project.

Thus, from literature survey gives a thorough knowledge off what works are previously done, which must not be repeated and giving idea or new methods or technology that can be adopted. Below are few papers that were that were closely related to the current work

XIN LI (2018) et al. Aiming to the interference with human body problem of the traditional arm exoskeleton, a non-humanoid arm exoskeleton is presented. The non-humanoid arm exoskeleton has a lager motion space, which is 20.8% more than the humanoid arm exoskeleton. The statics of the non-humanoid structure is analysed. The minimal interaction force control strategy between the arm exoskeleton and human is used in the control system for lifting load experiment, and the subjects can lift the load of 5Kg easily. Additionally, the response time of adjusted control system reduce 86.25% according to the control system without PID.

Markus Puchinger (2018) et al. considered the reduction of muscle activities and muscle forces with the gravity compensated RETRAINER upper limb exoskeleton were also analyzed to carrying out defined movements with healthy subjects. The EMG signals of the main active muscles as well as the kinematics of different defined motions were captured and compared. The joint kinematics and the joint moments were computationally determined using a 3D musculoskeletal model. The effectiveness of the upper limb gravity compensation could be shown in both mean values of EMG signals and resulting muscle forces, indicating that this compact and lightweight arm exoskeleton can serve as a powerful tool to support the rehabilitation process.

Won-Kyung Song (2017) et al. developed “The NRC Robotic Exoskeleton (NREX)”, an upper-extremity, rehabilitation robotic exoskeleton developed for daily life exercises, and treatment of hemiplegic or spinal-cord injured people, was improved by the National Rehabilitation Center, Korea. The shoulder module, which had restricted movement, was improved via additional passive-axis movements with rubber bands. In addition, NREX can now be used for either left- or right-arms by changing only two parts of the robot arm. We focus on the improvement of NREX mechanism to reduce cost and improve usability.

Faisal Khalid Kayshan et al. studied the challenging development in human-machine interface is to design product that serves the patient need to rehabilitate the injuries and to develop smart connection between the device and the human body. This exoskeleton design is required to perform one degree of freedom extension/flexion movement. The device consists of frame, motor, force sensor and casing. In this design the motor needs to develop the required amount of torque so the patient can perform the movement easily.

Pooja Jha (2018) et al. proposed the design of an efficient and comfortable option to commercial exoskeletons. Exoskeleton here refers to any wearable framework on the human body which eases and supports the muscles to perform work with lesser strain and greater comfort, using mechanical actuators and electrical power. The design proposed shall be capable of sensing the incentive to perform basic work procedures and routines making it natural and comfortable for the user to interact with and utilize this device, increasing its effectiveness and efficiency.

Thunyanoot Prasertsakul (2011) et al. studied human motion and use of motor control and motor drivers. They mentioned human motion is an important function which is related to the movement of the limbs. Patients who have injured or damaged of brain will be lost the movement function. The designed exoskeleton arm has degrees-of-freedom. Three degrees-of-freedom are at the shoulder joint, i.e. flexion/extension. The elbow joint has two degrees-of freedom that are flexion/extension and supination / pronation. Controlling the exoskeleton arm can be performed by the signals and a set of controller which composes of the electromyography amplifier, analog to digital convertor, motor control and motor driver.

Abhishek Gupta (2006) et al. worked on quality haptic interface is typically characterized by low apparent inertia and damping, high structural stiffness, minimal backlash, and absence of mechanical singularities in the workspace. In addition to these specifications, exoskeleton haptic interface design involves consideration of space and weight limitations, workspace requirements, and the kinematic constraints placed on the device by the human arm. These constraints impose conflicting design requirements on the engineer attempting to design an arm exoskeleton. In this paper, the authors present a detailed review of the requirements and constraints that are involved in the design of a high-quality haptic arm exoskeleton.

Research Methodology

This study consists of design calculation for certain parameters such as force torque and efficiency were required in order to get the dimensions and the specific motor required for the arm. Force gives and value for the amount of torque required to lift human arm. From this value we can conclude the torque required for the motor to work smoothly under the load. Measuring dimensions of human arm of team member to design the frame and materials election was done to keep the weight as low as possible in order to manage the weight properly as stated in objective. Once the design parameters are obtained, fabrication of exoskeleton was carried according to the designed values. Several operations such as cutting, drilling and grinding were done for the fabrication of beam of rectangular cross section and tightened with bolts and nut. Designs is made such a way assembling and dissembling could be done easily. As the product is finished, the prototype is checked for errors by conducting several test such as working in wearing load and voice testing were done to check the module for recognition of the words to activate the motor. The detailed methodology is presented in the following figure.

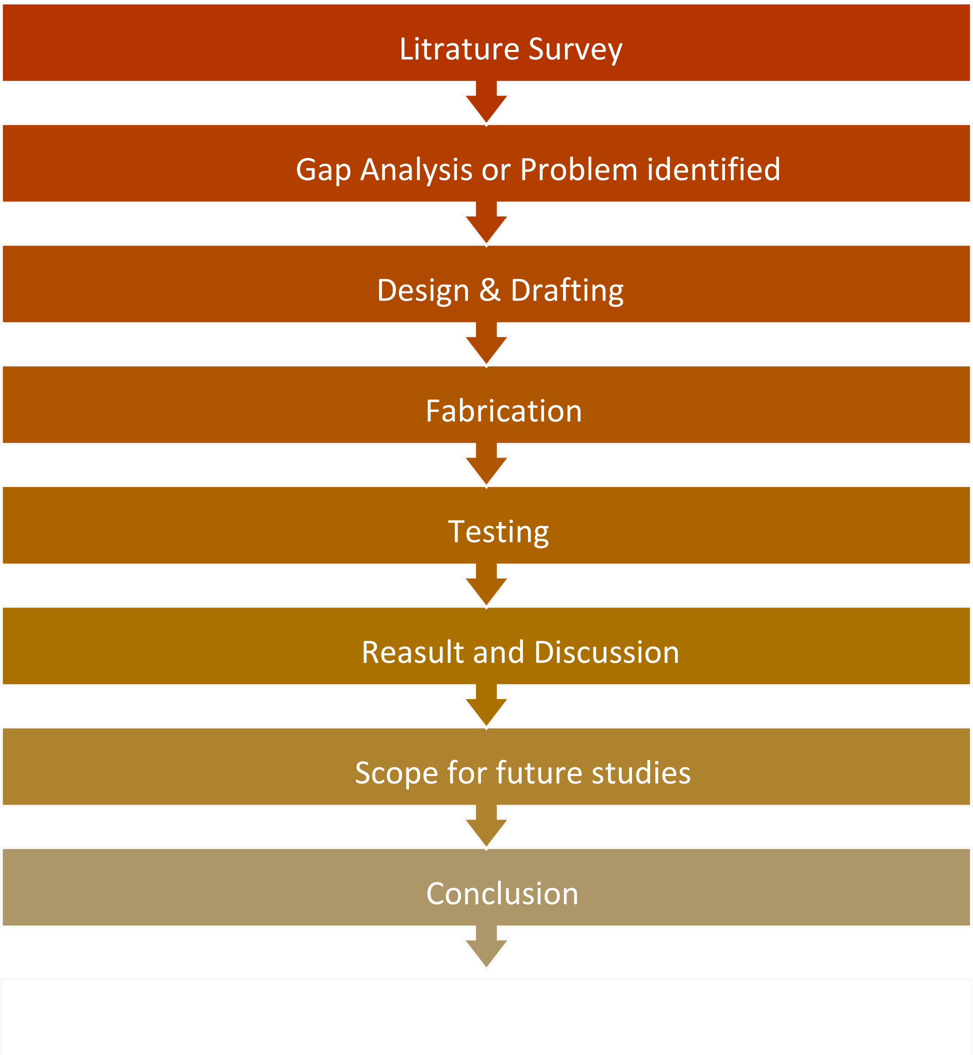


Figure .1: methodology

DESIGN CALCULATIONS

FORCE CALCULATION: Force can be described as a push or pull on an object. They can be due to phenomena such as gravity, magnetism, or anything that might cause a mass to accelerate.

The calculation of force is needed to identify the torque requirement. Firstly, the average weight of the hand is considered with the frame weight in kilograms and its summed up and multiplied with the gravitational force. Thus, giving result of force.

The formula for the force calculation is F = M*a .Assumed M = 2.64 kg considering average Human male forehand and hand weight 2.52 kg respectively and weight of aluminum flats has been taken 120gm approx. so that weight of the hand plus aluminum flats=2.64kg. Here F is the force required by the motor to lift the arm and the Aluminum flats. F = 2.64*9.81 = 25.89N

TORQUE CALCULATION: Torque is the measured ability of a rotating element, as of a gear or shaft, to overcome turning resistance. Torque is measured to identify the required torque for the motor to lift various loads under the command. Objective of this calculation is to identify the required torque needed for the arm to lift load. By this optimal motor would be installed which would neither less nor more power making it efficient.. Torque is calculated with force multiplied with distance. T=Torque required to lift the arm and the Aluminum flats,T = F * d = 25.89N * 0.230m = 5.95Nm ≈ 6Nm From this torque value, motor of same torque as acquired and installed at the elbow joint motor is also considered in a way it fits perfectly to the frame and not causing constrain during the movement of the arm.

MOTOR SPECIFICATIONS: As per torque required for the extension of the arm, Derry motor (figure .2) has been installed. Motor has required specifications as per the needs. Primary factors consider this motor is the torque output, less vibration and synchronous motor. Opted motor meets all three factors.

The motor consists of three brushes namely, common, low speed and high Speed. Two of the brushes will be supplied for different mode of operation. 12v high torque low rpm electric motor: Torque – 6Nm, Structure: Synchronous Motor

Figure.2: Derry Motor

ARM MEASUREMENT: Hand anthropometric data is considered for designing calculations Anthropometric is the study of science related to human body measurement. It is presented below table.1

Table.1: Hand Anthropometric data

Percentages of Total Body Weight

Segment	Males	Females	Average
Head	8.26	8.2	8.23
Whole Trunk	55.1	53.2	54.15
Thorax	20.1	17.02	18.56
Abdomen	13.06	12.24	12.65
Pelvis	13.66	15.96	14.81
Total Arm	5.7	4.97	5.335
Upper Arm	3.25	2.9	3.075
Forearm	1.87	1.57	1.72
Hand	0.65	0.5	0.575
Forearm & Hand	2.52	2.07	2.295
Total Leg	16.68	18.43	17.555
Thigh	10.5	11.75	11.125
Leg	4.75	5.35	5.05
Foot	1.43	1.33	1.38
Leg & Foot	6.18	6.68	6.43

Results and Discussion

After measurement of human arm and also considering anthropometric data open inclusion of 180 mm was taken but due to extra length required to link the lower arm to the motor, as it required extra space for the moment and to be attached this additional length was also consider in the front part so that human arm lay stable.

Drafting of various components: 2D-drafting of various components required for exoskeleton arm and actual fabricated parts are presented below in the following figures

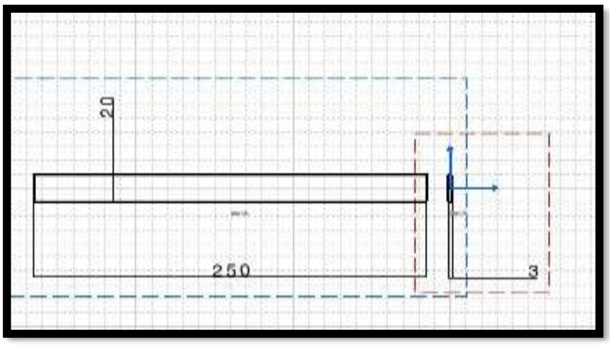


Fig.3: Fabricated Lower Human Arm support

Fig .4: Drafting of Fabricated Lower Arm support

2D model of the exoskeleton arm general layout

The general layout and components are seen in Figure. 5. It is the basic model of actual exoskeleton arm taken from 2D drafts for 2D modelling, this is further considered for 3D modelling for nearly actual projection of arm is done

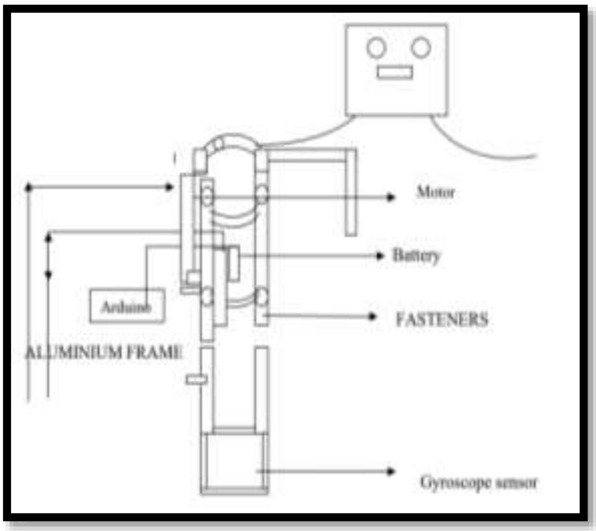
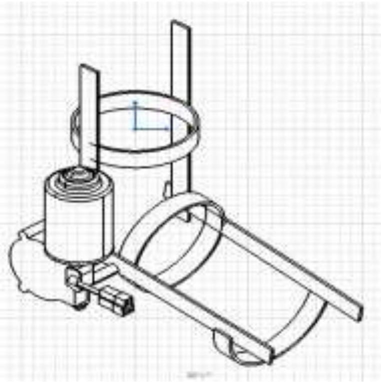


Figure.5: **2D model of exoskeleton arm**

Isometric view of exoskeleton arm: The 2-D drafting of final model of exoskeleton in an isometric view is shown in Figure.6 And this views shows the motor attached to the frame and the aluminum supports circular support to the arm providing the stability and connecting two arm frames



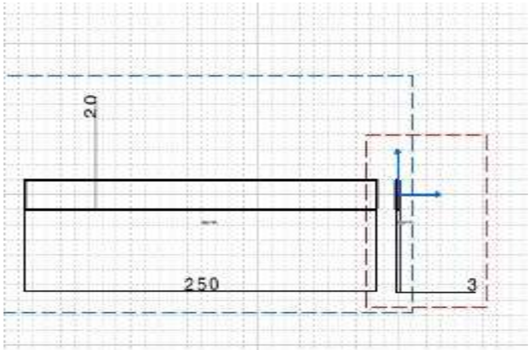


Figure.6: Isometric view of exoskeleton arm

Figure7: Lower arm support

3D CAD MODEL: A final 3D model of exoskeleton is shown in figure.8 the 3-D model is useful in checking preview of design and to rectify any errors

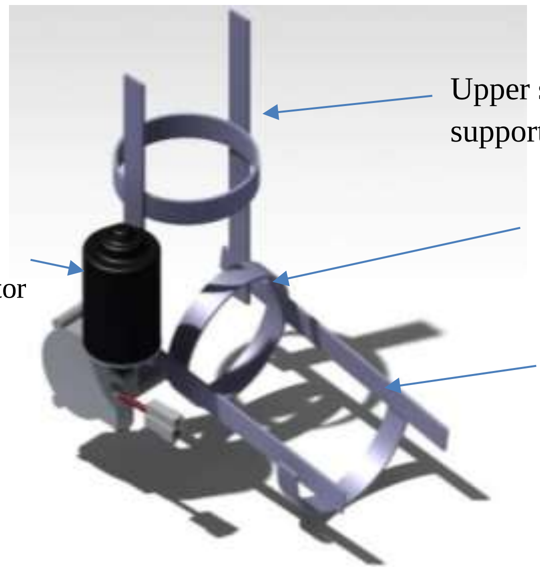


Figure.8: Isometric view of exoskeleton arm

The analysis of the model such as displacement, FEM and force reaction are done respectively.

A reaction force is the force applied to a structure when it rests against something. In analyzing a beam structure, it involves calculating what the reaction forces are at the supports due to the forces acting on the beam. A free body diagram of the entire beam can be used to determine the reaction forces. As the lower arm frame experiences the varying load table 2 is the data of the lower arm when subjected to load.

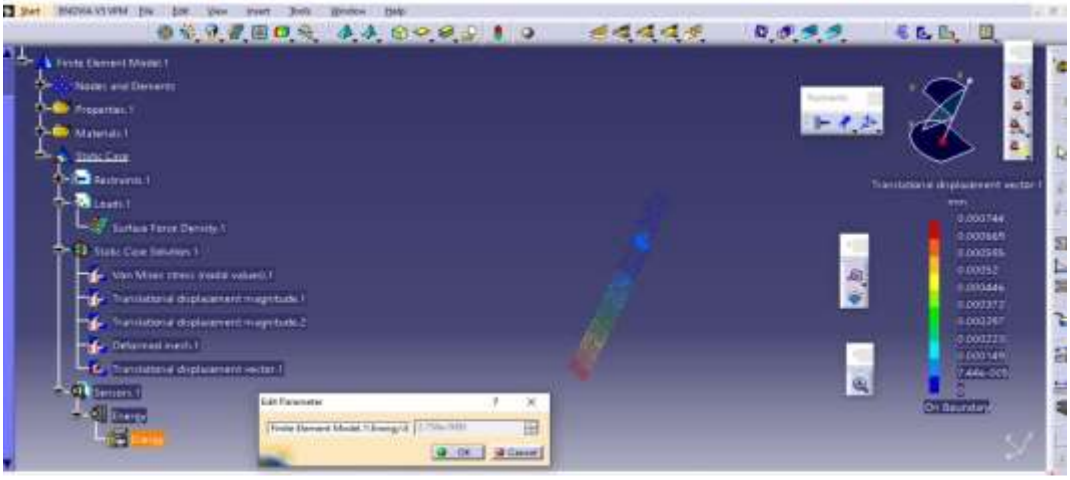


Figure.9: Displacement vector analysis of the lower arm

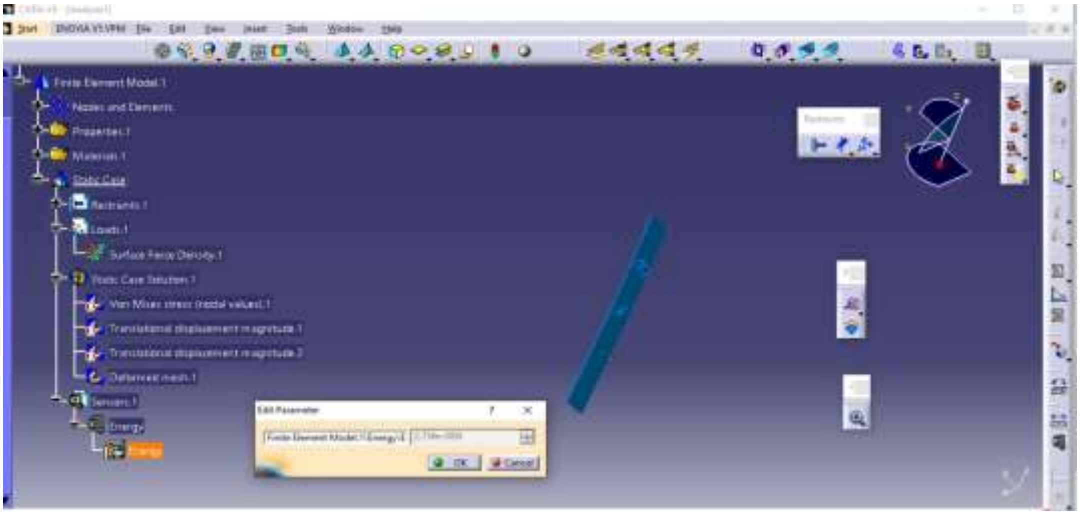


Figure.10: **FEM of the lower arm**

Components	Applied Forces	Reactions	Residual	Relative Magnitude Error
Fx (N)	-1.9870e-002	1.9870e-002	-1.3357e-015	1.2658e-013
Fy (N)	0.0000e+000	-6.7134e-015	-6.7134e-015	6.3619e-013
Fz (N)	0.0000e+000	2.6932e-015	2.6932e-015	2.5521e-013
Mx (Nxm)	0.0000e+000	6.7048e-017	6.7048e-017	1.1346e-013
My (Nxm)	-5.4936e-011	5.4936e-011	1.8038e-017	3.0524e-014
Mz (Nxm)	-1.4654e-009	1.4654e-009	3.4296e-016	5.8037e-013

Table 2: **Force reaction tabular column**.

The final fabricated model:

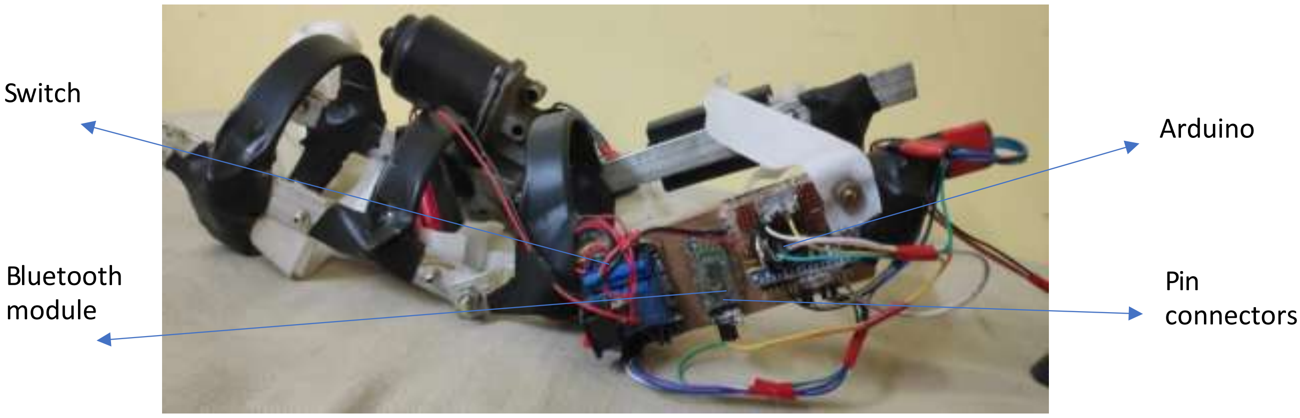


Figure.11: Final fabricated model

Testing: After finishing 2d and 3-d drafting actual model was fabricated and program for Flex code is written in C++ its common language used for Arduino programming. Finally its functionality is tested by conducting voice testing for various users to recognize voice and follow commands .It is observed that the model is working perfectly for different users. A weight test is conducted for testing the model capacity and it is observed that the model is capable of lifting weight along with hands up to 8 kgs.

Conclusion

The prophesied exoskeleton frame is functional and protected. The frame is being run through Arduino nano this exoskeleton arm gives new solution for the existing models which uses actuators to work and quite heavy. It challenges sturdy frames for all the components from this model of exoskeleton we can prove the motorized Skelton arm can be more efficient, light weight and can be much more advanced via adding more sensors. The traditional physiotherapy sessions would be replaced patients can recover themselves for minor issues or the aid for handicap people would be more comfortable and easier to employ. The model is cheaper compared to previously existing models.

The model is lighter as the model uses aluminum frames for lighter weight and simple structure. The incorporates both Flex sensors and voice recognition

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