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A STUDY OF WEARABLE ROBOTIC DEVICES DESIGNED FOR FLEXIBILITY AND POWER ASSISTING VOICE COMMANDS USING CATIA V5

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Abstract

A paralyzed person can use an exoskeleton arm to manipulate their wounded arm and regain full range of motion. Wearable robotic devices called exoskeletons are designed to provide the hand with speech and flex assistance. The majority of exoskeleton arms now on the market only have voice assistance or flex assistance; however, when voice and flex assistance are coupled, patients can use them more easily. The goal of this effort is to design and construct the exoskeleton arm in such a manner that it integrates the most support features while being practical. The exoskeleton is outfitted with an arm that has both a speech sensor and a flex sensor. Each component of the exoskeleton arm is initially designed using 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 is 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.

1. Introduction

Exoskeleton arms are mechanical devices that give human arms more power from a mechanical motor, which has several uses in the military, medical field, and load-bearing tasks. Only a few businesses have already started using exoskeleton devices for workers who need to handle heavy objects. The employment of this technique or technology in medical settings, such as physiotherapy sessions, is also possible.

The current exoskeleton arm is available with less degrees of freedom than the typical human arm, which may be onerous, but the patient just has to execute certain activities during the physiotherapy session in order to heal.

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 motion controls are unrelated to conventional human motions that create the associated arm motion. For example, bending of the "arm" of a prosthetic arm may induce a different movement than the shoulder, although in a normal human, the elbow and shoulder motions are separate. As a result, a whole new pattern of activity must be learned in order to make the exoskeleton arm usable, and final performance is limited since the degree of freedom required is limited, and the limits of the control system are too numerous. Exoskeleton technology will mostly be employed in the medical field, where it may be applied to enhance surgical accuracy or assist nurses in moving large patients.

There is every cause to hope for persons who have been gravely harmed but are not fully paralysed. They're likely to get even better. This device would add to the clinical toolkit accessible to those suffering from spinal cord injuries and other disorders.

It is quite difficult for a paralysed sufferer to perform anything. Even if they are unable to recover. The exoskeleton arm will be an ideal help for those patients, allowing them to be independent and do 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.

Following up on the particular codes for the components, the model fabrication and installation requirements for the flex and voice module are completed. For a product to operate, testing is an essential component. The model's functioning is examined through tests including voice and weight testing.

Statement of the Problem

Actuators, which are rather heavy and costly, are used to power the current exoskeleton versions. Consequently, a power assist type exoskeleton has been chosen for this paper as opposed to a more expensive power amplification device. By using a straightforward stepper motor and straightforward structural components, the weight issue with the earlier exoskeleton arms was resolved. 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 make the gadget smaller and lighter in order to limit user fatigue, maintain user comfort, and avoid any injuries or pain.

2. Review of Literature

A summary of many papers that have already been written on this subject. These publications were chosen based on the work done in developing the exoskeleton arm. The following few pertinent articles have been published here to help readers grasp the issue statement after extensive study was conducted on the subject. The following literature review is only a quick overview of the authors' work, and the shortcomings have been highlighted in accordance. This aids in identifying the problems that could serve as the project's goals.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

(2018) XIN LI et al. A non-humanoid arm exoskeleton is suggested as a solution to the typical arm exoskeleton's interference with human body issue. There is 20.8% greater motion room in the non-humanoid arm exoskeleton than in the humanoid arm exoskeleton. Analysis is done on the statics of the non-humanoid structure. The control system for the lifting load experiment uses a low interaction force control method between the arm exoskeleton and the person, and the participants can lift the 5 kg burden with ease. Additionally, compared to the control system without PID, the adjusted control system's response time was reduced by 86.25%.

With the gravity-compensated RETRAINER upper limb exoskeleton, Markus Puchinger (2018) et al. considered the reduction of muscle activities and muscle forces to perform predetermined movements with healthy subjects. Both the kinematics of the specified movements and the EMG signals of the primary active muscles were recorded and compared. A 3D musculoskeletal model was used to computationally calculate the joint kinematics and joint moments. Both mean EMG signal values and the resulting muscle forces could be used to demonstrate how well the upper limb compensated for gravity, demonstrating the potential of this small and light arm exoskeleton as a potent rehabilitation aid.

The National Rehabilitation Centre, Korea, enhanced "The NRC Robotic Exoskeleton (NREX)," an upper-extremity, rehabilitation robotic exoskeleton created by Won-Kyung Song et al. for daily life exercises for the treatment of hemiplegic or spinal-cord damaged persons. Additional passive-axis movements with rubber bands were used to improve the shoulder module's limited range of motion. Additionally, by switching out just two components of the robot arm, NREX can now be used as either a left- or right-arm. In order to cut costs and increase usefulness, we concentrate on improving the NREX mechanism.

According to research by Faisal Khalid Kayshan et al., designing a product that meets patients' needs for injury rehabilitation while also creating a clever link between the gadget and the human body is a hard advancement in human-machine interface. To accomplish an extension/flexion movement with one degree of freedom, this exoskeleton design is necessary. Frame, motor, force sensor, and casing make up the gadget. In order for the patient to move easily, the motor in this design must produce the necessary level of torque.

The concept of an effective and pleasant alternative to commercial exoskeletons was put out by Pooja Jha and colleagues in 2018. Any wearable human body structure that uses mechanical actuators and electrical power to support and relax the muscles so they may operate more comfortably and with less strain is referred to as an exoskeleton in this context. By making it easy and pleasant for the user to engage with and use this gadget, the suggested design will increase both its efficacy and efficiency. It will be able to sense the motivation to carry out routine tasks.

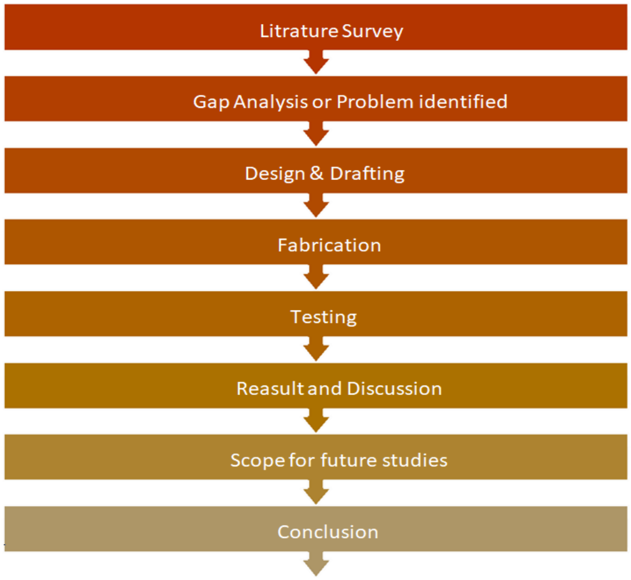
Human motion, motor control usage, and motor drivers were researched by Thunyanoot Prasertsakul (2011) et al. They said that the movement of the limbs is a crucial component of human mobility. Patients with brain injury or injuries will lose their ability to move. There are degrees of freedom in the developed exoskeleton arm. The shoulder joint has three degrees of mobility, or flexion and extension. Flexion and extension, as well as supination and pronation, are the two degrees of freedom available at the elbow joint. The signals and a set of controllers, which include an electromyography amplifier, an analogue to digital converter, a motor control, and a motor driver, may be used to operate the exoskeleton arm.

Quality haptic interfaces are often distinguished by low apparent inertia and damping, high structural rigidity, little backlash, and the lack of mechanical singularities in the workspace, according to studies by Abhishek Gupta (2006) et al. Exoskeleton haptic interface design also takes into account workspace needs, size and weight restrictions, and the kinematic limits imposed on the device by the human arm. The engineer attempting to build an arm exoskeleton is faced with contradictory design specifications as a result of these restrictions. The authors of this study provide a thorough analysis of the specifications and limitations that must be met in order to create an excellent haptic arm exoskeleton.

3. 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

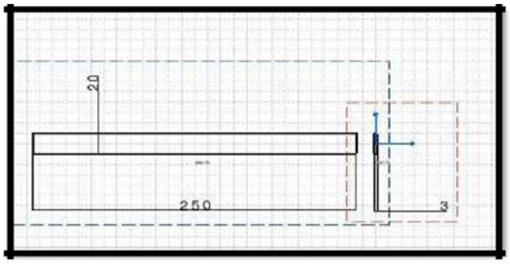
ARM MEASUREMENT: Hand anthropometric data is considered for designing calculations Anthropometric is the study of science related to human body measurement.

4. 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

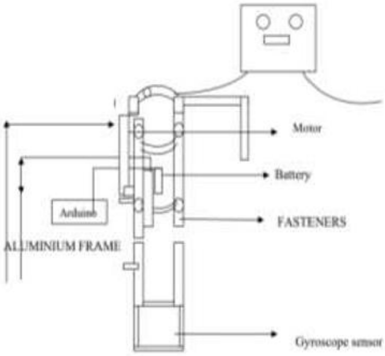
Fig.3: Fabricated Lower Human Arm support Fig .4: Drafting of Fabricated Lower Arm support



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

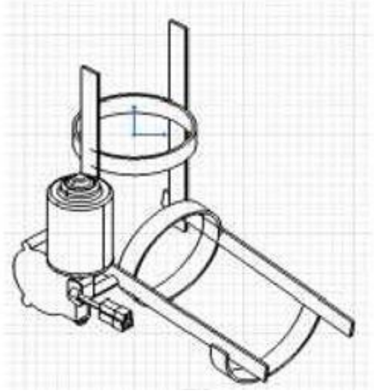
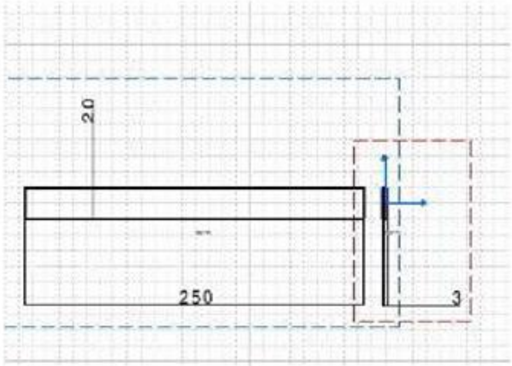
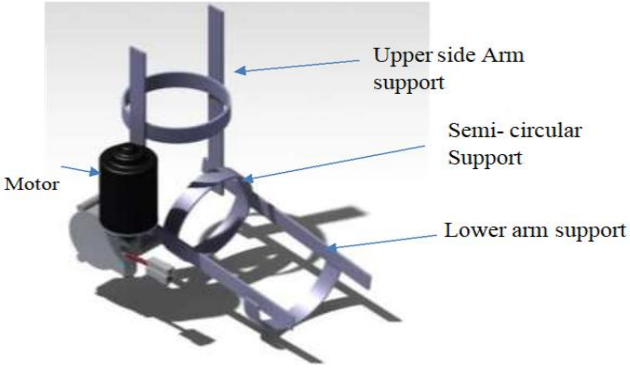


Figure7: Lower arm support



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 building experiences a reaction force when it rests against another object. Calculating the reaction forces at the supports as a result of the forces operating on the beam is a necessary step in the analysis of a beam construction. The reaction forces may be calculated using a free body diagram of the whole beam. 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

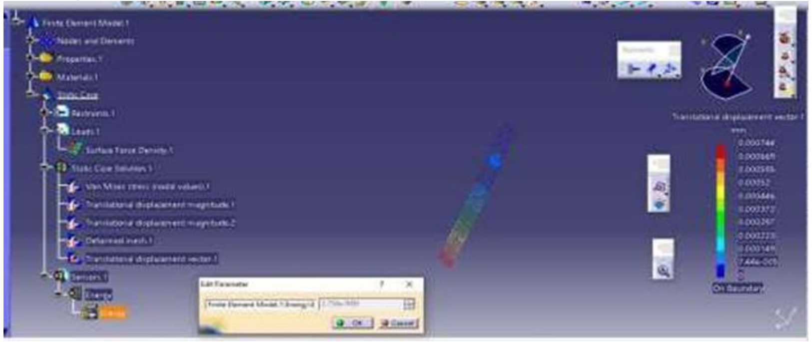
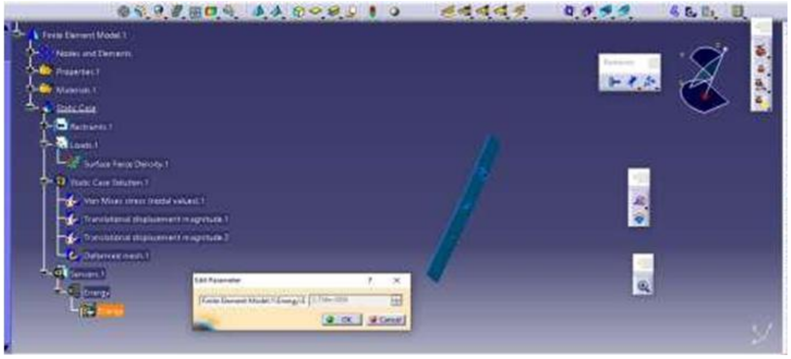
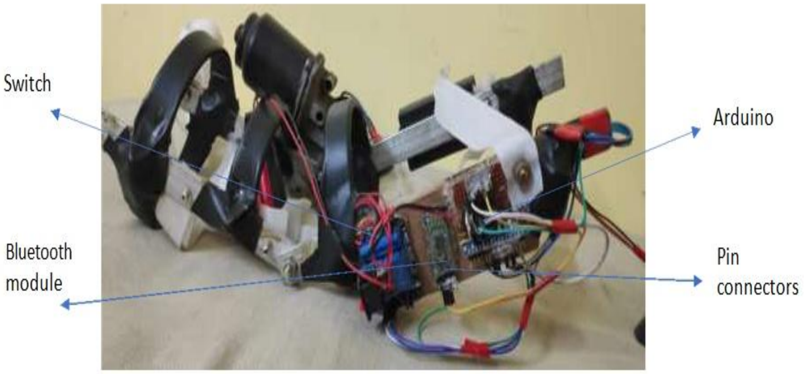


Figure.10: **FEM of the lower arm**



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 foretold exoskeleton frame is useful and secure. This exoskeleton arm, whose structure is controlled by an Arduino Nano, offers a novel alternative to the weighty and actuator-dependent previous variants. In order to demonstrate that the motorized Skelton arm may be more effective, lightweight, and much more advanced by including additional sensors, it challenges robust structures for all the components from this form of exoskeleton. Patients might recuperate on their own from minor ailments in place of the conventional physiotherapy sessions, or the help for persons with disabilities would be more commodious and simple to use. When compared to earlier versions, the new one is less expensive.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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