# Muscle Control Exoskeleton Robotic Arm

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*Abstract*— This is about developing robotic exoskeleton arm to assist motion of a hand of physically weak persons such as elderly, disabled, injured persons and can also be used as power exoskeleton. The robotic exoskeleton is controlled basically based on the electromyogram (EMG) signals. The Human– Machine interface was set at the neuromuscular level, by using the neuromuscular signal (EMG) as the primary command signal for the exoskeleton system. The EMG signal along with the joint kinematics were fed into a microprocessor which in turn predicted the muscle moments on the elbow joint. The exoskeleton structure under study was a two-link, two-joint mechanism, corresponding to the arm limbs and joints, which was mechanically linked (worn) by the human operator. In the present setup the shoulder joint was kept fixed at given positions and the actuator was mounted on the exoskeleton elbow joint. The operator has to carry manipulated external weight. The remaining weight on the arm will be carried by the exoskeleton actuator. We are using linear actuator for the movement.

***Keywords:*** Arm, Electromyography, Exoskeleton, Power Amplifiers, Robots

## I. Introduction

Powered exoskeletons are wearable robots designed to assist human movements. Integrating human and robotic machines into one system offers multiple opportunities for creating new assistive technologies that can be used in biomedical, industrial, and aerospace applications.

An exoskeleton is an external structural mechanism whose joints correspond to those of the human body. It is worn by the human and the physical contact between the operator and the exoskeleton allows direct transfer of mechanical power and information signals. This exoskeleton system is used for power amplification and as haptic device.

In utilizing the exoskeleton as a human power amplifier, the human provides control signals for the exoskeleton, while the exoskeleton actuators provide most of the power necessary for performing the task. The human becomes a part of the system and applies a scaled-down force compared with the load carried by the exoskeleton. For example, if the exoskeleton manipulates an object, the human may feel 20% of the load while the exoskeleton carries 80% of the load. In this setup the operator feels the interaction between the robotic arm tool-tip and the environment. Employing the exoskeleton as a haptic device is a relatively new technology aimed to simulate human interaction with virtual object simulated in virtual reality. The operator is immersed in a virtual realty environment wearing an exoskeleton. In that case a microcontroller is replacing the slave component. As a result a virtual object in that virtual environment can be touched by the operator, whereas the exoskeleton structure and its actuators provide a force feedback, emulating the real object including its mechanical and texture properties.

## II. Literature Gap

The exoskeleton arm are widely investigated and there are several methods to implement for the production and improvement of the arm. The methods are as follow

### A. *Neuro-fuzzy control of an exoskeleton arm*

This systems can be used for power assist of physically weak persons in daily activity and rehabilitation. It is important for the robotic exoskeleton, especially for medical or welfare use, to move according to the user's intention. The skin surface electromyogram (EMG) is one of the most important biological signals in which the human motion intention is directly reflected.

Human body is a typical complex fuzzy system. the biological signals such as skin surface EMG signal contains a lot of fuzziness. It is very difficult to obtain the same EMG signals for the same motion even with the same person. Hence this improve the signal sensitivity or we can control the signals.

### B. *Intention based control powered exoskeleton*

Electromyographical (EMG) signals have been frequently used to estimate human muscular torques. these methods provide valuable information to provide effectively support to the user. Nonetheless, an accurate estimate of muscle torque could be unnecessary to provide effective movement assistance to users. The natural ability of human central nervous system of adapting to external disturbances could compensate for a lower accuracy of the torque provided by the robot and maintain the movement accuracy unaltered, while the effort is reduced. This system gives only a rough estimate of the user muscular torque but does not require any specific calibration.

### C. *Pneumatic powered exoskeleton*

This provides a pneumatic powered system. It can only be used for a particular range as it requires air compressor for the operation. This can be operated manually by switch key and it is used as haptic devices(human computer interface) in industries. This is suitable for workers or where the man power requires. It is not recommended for the medical purpose as the system is bulky and has limited range as shown in figure below

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Fig. 1:

These are the different methods for the implementation, production and improvement in powered exoskeleton.

This paper is about EMG signal controlled by microcontroller. This project deals with movement of an arm by the use of an exoskeleton. An exoskeleton is an external structural mechanism with joints and links corresponding to those of the human body. In other words, designing the kinematics of an exoskeleton generally consists of trying to replicate human limb kinematics. The challenge is to build an exoskeleton system that is inexpensive, streamlined, and wireless. Our solution is unique in that it will be a low-cost, ergonomic device actuated through sensors measuring the user's motion. We have outlined the process of developing an exoskeleton arm which increases the load lifting capacity of a human. The structure of the system is built by the selected material C45

*D. Properties of steel C45 (1.0503)*

Weldability: Due to the medium-high carbon content it can be welded with some precautions. Hardenability: It has a low hardenability in water or oil; fit for surface hardening that gives this steel grade a high hardness of the hardened shell.
Why Mild steel C-45 is selected in our project.

1) Easily available in all sections.
2) Welding ability
3) Machinability
4) Cuttingablity
5) Cheapest in all other metals.

The structure is two link two joint mechanism the elbow is connected to the Linear actuator (TG100) which leads to the linear motion to angular motion. the actuator is shown in fig

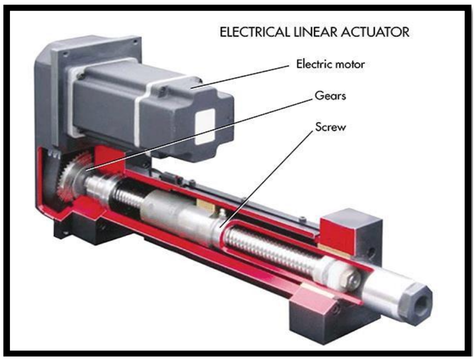


Fig. 2: TG100 Linear Actuator

The microcontroller Ardiuno Mega is used for the rectification and control of signals from the EMG sensors. Arduino Mega is a microcontroller it comes with more memory space and I/O pins as compared to other boards available in the market. There are 54 digital I/O pins and 16 analog pins incorporated on the board that make this device unique and stand out from others. Out of 54 digital I/O, 15 are used for PWM (pulse width modulation).A crystal oscillator of 16MHz frequency is added on the board. This board comes with USB cable port that is used to connect and transfer code from computer to the board. DC power jack is coupled with the board that is used to power the board. Some version of Arduino board lacks this feature like Arduino Pro Mini doesn't come with DC power jack. ICSP header is a remarkable addition to Arduino Mega which is used for programming the Arduino and uploading the code from the computer. Arduino

Mega is specially designed for the projects requiring complex circuitry and more memory space. Most of the electronic projects can be done pretty well by other boards available in the market which make Arduino Mega uncommon for regular projects. However, there are some projects that are solely done by Arduino Mega like making of 3D printers or controlling more than one motors, because of its ability to store more instructions in the code memory and a number of I/O digital and analog pins.

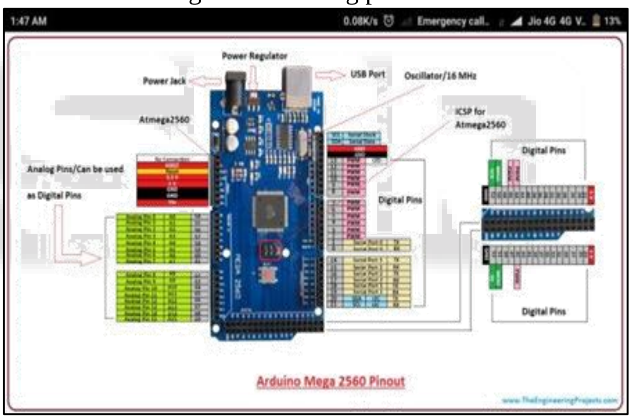


Fig. 3: Programming

Arduino Mega 2560 can be programmed using Arduino Software called IDE which supports C programming. The code you make on the software is called sketch which is burned in the software and then transferred to the board through USB cable. This board comes with a built-in bootloader which rules out the usage of an external burner for burning the code into the board. The bootloader communicates using STK500 protocol. Once you compile and burn the program on the board, you can unplug the USB cable which eventually removes the power from the board. When you intend to incorporate the board into your project, you can power it up using power jack or Vin of the board. Multitasking is another feature where Arduino mega comes handy. However, Arduino IDE Software doesn't support multitasking feature but you can use other operating systems like Free RTOS and RTX to write C program for this purpose. This gives you the flexibility of using your own custom build program using ISP connector.

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## III. METHOD

### A. Experimental System

The experimental exoskeleton structure is consisted of a two-link, two-joint mechanism corresponding to the upper and the lower arm and to the shoulder and elbow joints of the human body. The system included a weight plate (external load) that can be attached to the tip of the exoskeleton forearm link. The mechanism was fixed to the wall and positioned parallel to the sagittal plane of the operator. The human/exoskeleton mechanical interface included the upper arm bracelet, located at the upper arm link, and a handle grasped by the operator. This two-joint mechanism was used as a 1 DOF system by fixing the system shoulder joint $(\theta_S)$ at specific angles in the range of $0^o$ –$180^o$. The elbow joint $(\theta_E)$ was free to move in an angle range of $0^o$ –$145^o$ and included built-in mechanical constraints which kept the exoskeleton joint angle within the average human anthropometric boundaries. Since the human arm and the exoskeleton were mechanically linked the movements of the forearms of both the human and the exoskeleton were identical.

The basic purpose of the exoskeleton system as an assistive device is to amplify the moment generated by the human muscles relative to the elbow joint, while manipulating loads. The exoskeleton's elbow joint was powered by a dc servo motor with a stall torque of 360 Nm equipped with a planetary gearbox with a gear ratio of 1 : 20 and a maximal output torque of 40 Nm. Due to the encoder location and the high gear ratio, the practical encoder's resolution for measuring the joint angle was $0.0036^o$. This setup incorporated a dc motor with the highest torque- to-weight ratio that was available on the commercial market at that time with a power consumption that could be provided by a battery. A high energy density of the power supply and an actuator with a high torque-to-weight ratio are two key features of the exoskeleton system as a self-contained mobile medical assistive device for the disabled community. Limits imposed by present technology on these two key components along with design requirements for developing a compact system with a potential of serving as a medical assistive device for disabled person restricted the payload to be 5 kg. However, this biomedical oriented design does not restrict the generality of the exoskeleton concept or its operational algorithms. Using other actuation systems, like hydraulic system increases the load capacity substantially.

The exoskeleton forearm was extended by a rod with a special connector for attaching disk- type weights (external load). Two force sensors were mounted at the inter-faces between the exoskeleton and the tip carrying the external load and between the exoskeleton and the human hand. The first load cell, inserted between the rod holding the external load and the exoskeleton forearm link, measured the actual shear force, normal to the forearm axis, applied by the external load. The second load cell was installed between the handle grasped by the human hand and the forearm link of the exoskeleton. This load cell measured the shear force applied by the operator to the handle. Multiplying the sensors' measurements by the corresponding moment arms indicated the moments applied by the weights and by the human hand relative the elbow joint.

Surface EMG electrodes were attached to the subject's skin by adhesive disks at locations. for measuring the EMG signal of the Biceps Brachii and Triceps Brachii medial-head muscles. The signals were gained by EMG amplifiers using a gain factor in the range of 2000-5000 (depending on the subject). The EMG signals and the load cell signal were acquired by an A/D convertor with Arduino UNO, The entire data set was recorded simultaneously and stored in a microcontroller and in particular hardware for later off-line analysis and simulation.

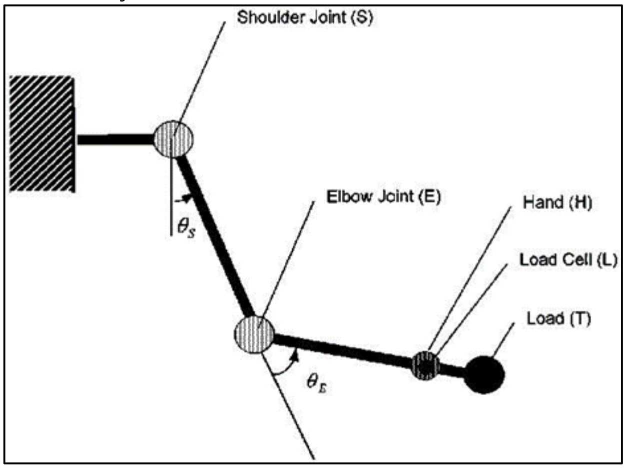


Fig. 4: System Component

A special real-time software, for operating the system, was written in C and run on a PC-based platform. The software was composed of three main modules. The first module dealt with the hardware/software interface. It controlled the interaction between the PC and the external motor driver and the sensors, through a D/A and an A/D card. The second module included the automatic code generated by the MATLAB- Simulink Real-Time toolbox. The third module was the user interface module which allowed to set various run time operational parameters. All the modules were compiled and linked for generating an efficient real-time software.

### B. EMG Signal Processing and the Muscle Model

The human elbow joint complex can be considered as a 2 DOF joint including flexion– extension and pronation–supination joint movements. These movements are enabled by two sets of muscle groups: 1) the primary flexor muscles—the Brachialis, the Biceps Brachii, and the Brachoradialis and 2) the primary extensor muscle— Triceps Brachii. Out of the three flexor muscles the Fig: Hill type muscle model (block diagram)

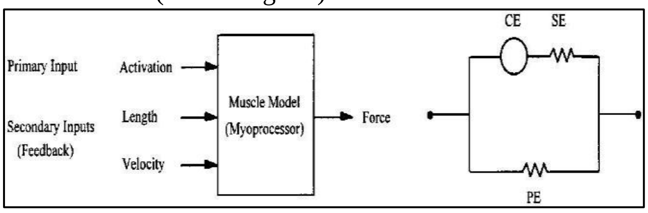


Fig. 5: block diagram

Brachialis has been referred to as a flexor par excellence of the elbow. Due to the fact that it is almost impossible to measure the EMG signals of the Brachialis by noninvasive techniques, the Biceps Brachii muscle was selected to represent the activation level of the joint flexor

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muscles group. As opposed to the elbow flexion movement that is preformed by three different muscles, the main elbow extension muscle is the Triceps Brachii that composed of three separate heads. The medial head is always active and appears to be the prime extensor of the elbow whereas the lateral and long heads act in reserve. Based on this finding the Triceps Brachii medial- head was selected to represent the activation level of the joint extensor muscle group.

The algorithm for estimating the normalized muscle activation level (NAL), based on raw EMG signals, follows the signal processing procedure summarized in Fig. It includes

1) A high-pass filter;
2) Full signal rectification (absolute value);
3) A lowpass;
4) A signal normalization with respect to the EMG mean signal during maximal voluntary isometric contraction.

The myoprocessor which was implemented in the present work was a Hill-based (HB) muscle model whose inception dates back to the classical paper of Hill. HB models are almost universally accepted in bioengineering as an appropriate mathematical representation of muscle mechanics.

A HB muscle model consists of three elements:

1) A contractile element (CE) which represents the force generated by the active muscle fibers using the muscle chemical energy;
2) A series element (SE) which models the mechanical response of muscle to rapid length changes
3) A parallel element (PE) which simulates the passive resistance of muscle to stretch generated by the passive soft connective tissue, including the tendon and the non active muscle fibers.

The only modification made to this formulation included a generalized, continuous, dimensionless form of the CE force–velocity characteristics which synthesized both the shortening and the lengthening phases in one mathematical equation.

## IV. Conclusion

In this paper, a robotic exoskeleton for human upper-limb motion assist, an Arduino controlled robotic exoskeleton arm, and its adaptation method in order to assist the motion of physically weak persons such as elderly, disabled, and injured persons. The proposed controller consists of first input signal selection stage, second signal filtration and amplification, and third control stage. The skin surface EMG signals, which directly reflect the human motion intention, are mainly used as controller input signals. In the proposed Arduino UNO control method, the main-effect of each muscle is taken into account in the antecedent part and the subeffect of some muscles is taken into account in the consequent part. The effectiveness of the proposed system was evaluated by experiment.

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