International Journal of Interdisciplinary Innovative Research &Development (IJIIRD)
ISSN: 2456-236X
Vol. 05 Special Issue 01 | 2020

Exoskeleton Arm with Pneumatic Muscle Actuation

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ABSTRACT

Exoskeletons are a type of skeletal architecture that surrounds the wearer instead of the traditional internal design. Exoskeleton wearable robots follow the same principle of having the pivotal structures outside its user allowing the mechanical system to be used as a suit. Similar exoskeleton structures can be used as input devices for easy human control of separate mechanisms, as is being applied in surgical procedures allowing the remote control of specialized equipment, and in virtual environment interaction where the user can interact with objects rendered inside of digital devices. Such exoskeletons are called Step Rehabilitation Robots.[4].

KEYWORDS- Pneumatic, actuation, portable, OTM system, Rehabilitation.

1. INTRODUCTION

Exoskeleton wearable robots have the same principle of having the pivotal structures outside its user allowing the system to be used as a suit. This type of robotics allows an intuitive and natural interaction between human and machine where the users are not required to steer nor actively control the robot but instead have only to move their body while the exoskeleton follows. One of the proposed main uses for an exoskeleton would be enabling a person to carry heavy objects while running or climbing stairs. Another area of application could be medical care, nursing in particular to help nurses lift and carry patients. We wanted our design to, like the previous designs, have some manner of storing energy in order to release the energy in a controlled fashion. That way, we could have one hydraulic pump running continuously, similarly to how the previous OTM systems could have an electric motor running continuously. We also decided that our design had to be a closed system; all the water used had to be constantly re-circulated throughout the system.

Because this system was supposed to be worn on a body as an Exo-musculature system, we needed to make sure it was portable and light. We set the parameters that it had to be no larger than a child's backpack and no heavier than 45 Newtons. Again, because this needed to be worn by people and might have to be used for long hours, we set the parameter that our project had to be able to run nonstop for at least two hours. [13].We wanted to be able to show the ability of this system to be used in real-world environments. We wanted our system to be able to lift at least a gallon of milk. This meant that we had to be able to generate 100 Newtons of force.

We also had three requirements in relation to our system being an OTM system. Firstly, it must be modular. It has to be able to have more actuators connected or removed as necessary. Related to that, we also wanted to be able to control each actuator individually. We needed to have the ability to control different actuators at different times, while the pump was running in order to demonstrate the OTM nature of the system. Lastly, we decided that the system needs to be able to control at least two degrees of freedom at once. The purpose of an OTM system is to use one motor or pump to control multiple degrees of freedom. We wanted to connect at least two actuators, controlling two separate degrees of freedom to our system.

2. LITERATURE REVIEW

"Design of a Haptic Arm Exoskeleton for Training and Rehabilitation", Abhishek Gupta, Student Member, IEEE, and Marcia K. O'Malley, Member, IEEE[6] 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.

"Design of Exoskeleton Arm For Enhancing Human Limb Movement ", Thunyanoot Prasertsakul, Teerapong Sookjit, and Warakorn Charoensuk Publishedin: Proceedings of the 2011 IEEE International Conference on Robotics and Biomimetics December 7-11, 2011, Phuket, Thailand [5] 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- offreedom 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.

"PID Control forth Robotic Exoskeleton Arm: Application to Rehabilitation ", GuangyeLiang,WenjunYe ,QingXie[7] This paper enlights the PID control of exoskeleton robot armused for assisted rehabilitation. The developed exoskeleton arm consists of 5 joints, which process merits of back drivability, precise positioning capabilities and zero backlash due to its embedded Harmonic drive transmission (HDT) and Elmo driver. The experiments are conducted to verify the effectiveness of the proposed system and control approach.

"Design of Exoskeleton Robotic Hand/Arm System for Upper Limbs Rehabilitation Considering Mobility and Portability ", Yong-Kwun Lee Department of Biorobotics, Kyushu Sangyo University, Fukuoka, 813- 8503, Japan Published in:The 11th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI 2014) Nov. 12-15, 2014 at Double Tree Hotel by Hilton, Kuala Lumpur, Malaysia[8]

Hand and arm movement disorders can be caused by stroke, fractures, ligament tear or loss of strength due to aging. Stroke is a disease accompanying partial paralysis in the muscle contraction and expansion, but stroke patients can be improved by rehabilitation training or physiotherapy. To increase the effectiveness of rehabilitation training, continuous and repeated movement training with a physiotherapist is needed and enhancement can be achieved in the process by using such designs.

"Power-Augmentation Control Approach for Arm Exoskeleton Based on Human Muscular Manipulability", RokGoljat, Jan Babi, Tadej Petri, Luka Peternel, Jun Morimoto[9]

In the past years, robots have been gradually moving from industrial environments into the human daily lives. The main purpose of such robotic systems is to assist humans in various real-life tasks. One of such promising robotic systems are exoskeletons, which are designed to enclose the human body and provide a direct assistance to the motion. The two main applications of exoskeletons are rehabilitation and power augmentation.

"Improvement of Upper Extremity Rehabilitation Robotic Exoskeleton, NREX ",Won-Kyung Song and Jun-Yong Song Department of Rehabilitative and Assistive Technology, National Rehabilitation Center, Published in:2017 14th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI) June 28 - July 1, 2017 at Maison Glad Jeju, Jeju, Korea[10]

The NRC Robotic Exoskeleton (NREX), developed by the National Rehabilitation Center (NRC), is a lightweight, exoskeleton robot capable of assisting movements related to daily life activities. NREX has an exercise function for movements of hands and arm via minimal number of electrical motors. It is based on the movement of one wrist joint and one elbow joint. Additionally, NREX has a hand grip function.

"Design, Analysis and Experiment of A Non- humanoid Arm Exoskeleton for Lifting Load", Xin Li, ZhengweiJia, Xiang Cui, Lijian Zhang Research Center of Human Performance Modification Technology Beijing Institute of Mechanical Equipment Beijing, China Published in: 2018 The International Conference of Intelligent Robotic and Control Engineering.[4]

Arm exoskeleton is widely used in medical and industrial areas because of its assistant ability. Many universities and institutes do some relevant works describes a robotic-arm exoskeleton that uses a parallel mechanism inspired by the human forearm to allow naturalistic shoulder movements. The patients who survived stroke and the elderly who do not have enough strength to move their limbs freely presents the development of the exoskeleton system for amplifying human strength.

"Experimental Modelling of Pneumatic Artificial Muscle Systems ", Manthan V. Pawar[2] Pneumatic Artificial Muscles (PAMs) are widely used in humanoid and exoskeletons for force and mobility assistance. PAM technology is currently under study and facing problems such as low efficiency and less actuation. At Robolab Technologies, PAMs are used in our exoskeleton system called Assistive Pneumatic Muscle Arm (APMA) and has countered such problems.

"The RETRAINER Light-Weight Arm Exoskeleton: Effect of Adjustable Gravity Compensation on Muscle Activations and Forces", Markus Puchinger, NithinBabuRajendraKurup, Thomas Keck, Johannes Zajc, Michael Friedrich Russold and Margit Gföhler2018Published in:2018 7th IEEE International Conference on Biomedical Robotics and Biomechatronics (Biorob) Enschede, The Netherlands, August 26-29, 2018[1] The recovery of arm movements is one of the most important goals in the processs of rehabilitation in order to avoid long-term disability.. In this study, the reduction of muscle activities and muscle forces with the gravity compensated RETRAINER upper limb exoskeleton were analyzed carrying out defined movements with healthy subjects.

2.1 Comparative Study

Sr. No.	Year of Publication	Title	Methodology
1	2006	Design of a Haptic Arm Exoskeleton for Training and Rehabilitation [6]	The design of a five- egree- of-freedom haptic arm exoskeleton for training and rehabilitation in virtual environments is presented.
2	2011	Design of Exoskeleton Arm for Enhancing Human Limb Movement [5]	Controlling the exoskeleton arm can be performed by the electromyography signals and a set of controllers which composes of the electromyography amplifier, analog to digital convertor, motor control and motor driver.
3	2012	PID Control for the Robotic Exoskeleton Arm: Application to Rehabilitation[7]	The developed exoskeleton arm consists of 5 joints, which process merits of back drivability, precise positioning capabilities, and zero backlash due to its embedded Harmonic drive transmission (HDT) and Elmo driver.
4	2014	Design of Exoskeleton Robotic Hand/Arm System for Upper Limbs Rehabilitation Considering Mobility and Portability[8]	light robot aid- robot with three fingers of 9 DOF
5	2017	Power-Augmentation Control Approach for Arm Exoskeleton Based on Human Muscular Manipulability[9]	In this paper the author presents a control method for the exoskeleton arm that takes into account the muscular force manipulability of the human arm.
6	2017	Improvement of Upper Extremity Rehabilitation Robotic Exoskeleton, NREX[10]	NREX has a hand grip function. The shoulder has three degrees- of-freedom manual joints without electrical actuators.
7	2018	Design, Analysis and Experiment of A Non-humanoid Arm Exoskeleton for Lifting Load[4]	The design and kinematic analysis of a 5 DOF upper limb powered robotic exoskeleton for rehabilitation
8	2018	Experimental Modelling of Pneumatic Artificial Muscle Systems Designing of Prosthetic Robotic Arm[2]	This paper talk about the Pneumatic Artificial Muscles (PAMs)
9	2018	The RETRAINER Light-Weight Arm Exoskeleton: Effect of Adjustable Gravity Compensation on Muscle Activations and Forces[1]	Humeral rotation and wrist pro are either controlled by residual muscle forces or locked at customized backrest.

3. PROBLEM IDENTIFIED

The requirements of an active upper-limb exoskeleton are different in accordance with the purpose of the device. The upper-limb exoskeleton exoarms also directly interact with the human user, safety becomes an important requirement. The exoskeleton for wrist motion assist has provided the axes deviation of wrist flexion/extension axis and wrist radial/ulnar axis. Movement of the center rotation of shoulder joint with respect to to the upper-arm motions must cancel out the ill effect caused by the design. If upper-arm motions also have to be assisted by the exoarm as well as forearm motion, a mechanism that allows moving of the center of rotation of the shoulder joint must be considered in the upper-limb exoskeleton. This mechanism is considered in to cancel out the ill effects caused by the position difference between the center of rotation of the exoarm shoulder and that of the human shoulder. The mechanical singularity should not be occurred within the workspace of the exoarm. Some designs havemeasured this in their designs. Although some of the above explained vital requirements have been fulfilled, researchers should consider following aspects. The exoarm for wrist motion assist should have individual axis for wrist flexion, wrist extension, wrist radial deviation and wrist ulnar deviation motions. Mechanical designs of upper-limb exoskeletons can beenhanced to reduce their inertia. The weight of the exoarm system also affects its portability

In this present world there is huge need of man power, so there must be an alternative to reduce this problem. Even in industrial application more human resources are required for daily work and there is more load carrying process. All these above work can notdone by humans only. To overcome this situation pneumatic exoskeleton system is made to ease the work and reduce stress of primary area for exoskeleton technology, where it can be use for enhanced precision during surgery or as an assist to allow nurses to move heavy patients. [9].

4. PROPOSED SYSTEM

We were looking at several ways to store energy and actuate movement with a hydraulic system. For storing energy, we looked at different designs of hydraulic accumulators. We wanted a way of slowly storing high pressures and volumes of water in an accumulator, and then being able to release it at once into an actuator. [7].We were looking at storing the water in an elastic container, which would help propel the fluid out when there was a high difference in pressure. For the actuator, we wanted basically a compliant, soft robotics alternative to hydraulic pistons and cylinders. When we combined the idea of the elastic accumulator with the actuator we found out our main design concept. We found out that if we used the contracting movement of the elastic as the muscle force, creating a tensile force rather than a compressive force, it could act similarly to an actual biological muscle. At that point, we needed to figure out a way to restrain the elastic so that it can only expand and contract in one dimension. If we were to connect an elastic bladder like it was human bicep, when we filled it with fluid, it would obviously expand in all directions. We figured that if we used a long elastic tube instead of a bladder, surrounded by a wrinkled, inelastic fabric material, the inelastic material would prevent the elastic tube from expanding radically.

5. WORKING OF PROPOSED SYSTEM

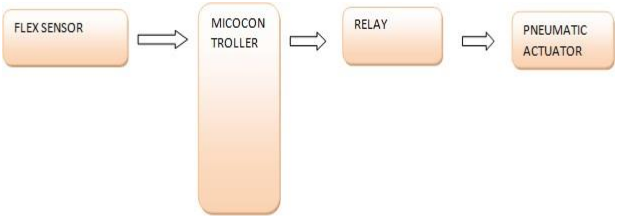
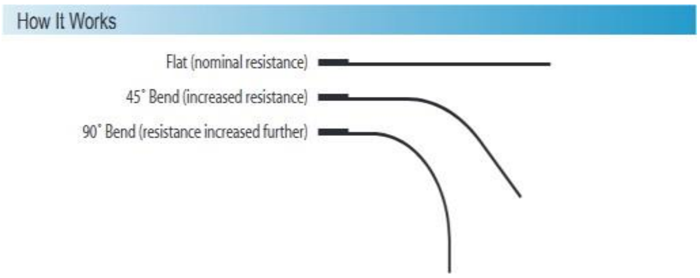


Fig. 1. Proposed Block Diagram

5.1 FLEX SENSOR

Fig. 2. Flex sensor

A flex sensor or bend sensor measures the amount of deflection or bending. Generally, the sensor is stuck to the surface, and resistance of sensor element is changed by bending the surface. As we know that the resistance is directly proportional to the amount of bend it is used as a goniometer, and it is called flexible potentiometer.



5.2 RELAY

Relays works as switches that open and close circuits electromechanically or electronically. Relays manage one electrical circuit by opening and closing contacts in another circuit. As relay diagrams show, when a relay contact is normally open (NO), there is an open contact when relay is not energized. When a relay contact is Normally Closed (NC), there is a closed contact when relay is not energized. In both cases, applying electrical current the state is changed of the contacts. Relays areused to switch small currents in a control circuit and do not generally control power consuming devices. Nonetheless, relays can "control" bigger voltages and amperes by having amplifying effect because a when a small voltage is applied to relay coilit can result in large voltage being switched by the contacts. Protective relays can save damage of the equipment by detecting electrical abnormalities, including overcurrent, undercurrent, overloads and reverse currents. Moreover, relays are also used to switch starting coils, heating elements, pilot lights and audible alarms.

Figure 3: Relay

5.3 ATMEGA 16

Atmega16 is a 40-pin low power microcontroller developed using CMOS technology. CMOS is a technology which is mostly used for making integrated circuits. It has low power consumption and high noise immunity.

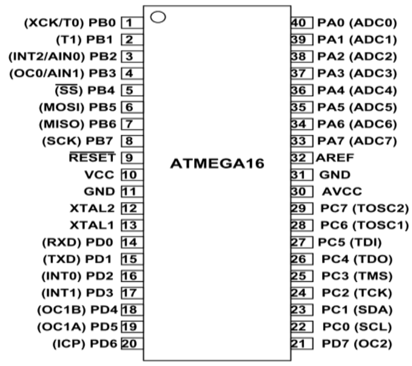


Figure 4:Pin diagram

Atmega16 is an 8-bit controller developed by AVR advanced RISC (Reduced Instruction Set Computing) architecture. AVR is family of microcontrollers made by Atmel in 1996.

It is a single chip computer that have CPU, ROM, RAM, EEPROM, Timers, Counters, ADCinbuild in it andhave four 8-bit ports called PORTA, PORTB, PORTC, PORTD where each port has 8 I/O pins.

Atmega16 has built-in registers which is used to make a link between CPU and external peripherals devices. CPU is not directly connected with external devices. It gives input by reading registers and can read output by writing registers. Atmega16consistsnof two 8-bit timers and one 16-bit timer. All these timers can be used as counters when they are optimized to count the external signal.

5.4 PNEUMATIC ACTUATOR

A Pneumatic actuator mainly has a piston or a diaphragm which generates the intentional power. It keeps the air in the upper portion of the cylinder, which causes the air pressure to force the diaphragm or piston to move the valve stem or rotate the valve control element.

Valves require little pressure to run and generally double or triple the given input force. The bigger is the size of piston, the bigger is the output pressure. Having a larger piston is alsso good if air supply is low, permit the same force with less input. These pressures are big enough to crush items in the pipe. On 100 kPa input, one could lift a small car.This pressure is transferred to the valve stem, which is connected to either the valve plug. Larger forces are used in high pressure or high flow pipelines to allow the valve to overcome these forces, and allow it to move the valves moving parts.

Figure 6: Pneumatic actuator

5.5 MOTOR DRIVERS

L293D is a basicl Motor driver IC which allows DC motor to drive on both the direction. L293D is a 16-pin IC which can control a set of two DC motors at the same time in any direction. It means that one can control two DC motor with a single L293D IC.In a single L293D chip there are two h-Bridge circuit inside the IC which can rotate two dc motor.H-bridge is a circuit which allows the voltage to be flown in both the direction.H- bridge IC are ideal for driving a DC motor.Due its size it is very highly used in robotic application for controlling DC motors.

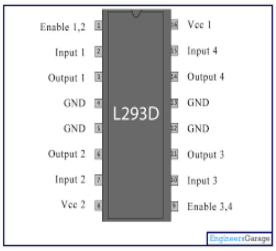


Figure 7: L293D Motor Driver

6. RESULT AND DISCUSSION

The proposed exoskeleton arm successfully addresses the issue of expensiveness prominent in the entire exoskeleton industry and implements simple solutions to reduce its costs. It uses safe, portable and efficient power supply and thus is environmentally friendly. Hence it is clear that there is a huge scope that the exoskeleton industry will gradually emerge to be highly profitable and will make a huge impact the sectors of defense, industry as well as domestic households


Figure 8 (a)


Figure 8 (b)


Figure 8 (c)

7. CONCLUSION

The proposed exoskeleton arm successfully addresses the issue of expensiveness prominent in the entire exoskeleton industry and implements simple solutions to reduce its costs. It uses safe, portable and efficient power supply and is environmental friendly. Hence it is clear that there is a huge scope that the exoskeleton industry will gradually emerge to be highly profitable and will make a huge impact the sectors of defense, industry as well as domestic households, if more such cheaper exoskeletons are made. This industry has the potential to be the leading industry in the near future.

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