Journal of Engineering Sciences
Vol 10, Issue 12, DEC/2019
ISSN NO:0377-9254

A LIGHTWEIGHT ROBOTIC ARM WITH PNEUMATIC MUSCLES FOR ROBOT LEARNING

[1]Summiya Sabeen, [2]Dr. Mohammad Iliyas
[1]PG Scholar, MTech, Dept of Embedded Systems, Shadan College of Engineering and Technology HYD, T.S.
summiya.sabeen@gmail.com
[2]Professor & HOD, Dept of ECE, Shadan College of Engineering and Technology HYD, T.S.
ilyas.ece@gmail.com

ABSTRACT

Versatile motor skills for hitting and throwing motions can be observed in humans already in early ages. Future robots require high power-to-weight ratios as well as inherent long operational lifetimes without breakage in order to achieve similar perfection. Robustness due to passive compliance and high-speed catapult-like motions as possible with fast energy release are further beneficial characteristics. Such properties can be realized with antagonistic muscle-based designs. Additionally, control algorithms need to exploit the full potential of the robot. Learning control is a promising direction due to its the potential to capture uncertainty and control of complex systems. The aim of this paper is to build a robotic arm that is capable of generating high accelerations and sophisticated trajectories as well as enable exploration at such speeds for robot learning approaches. Hence, we have designed a light-weight robot arm with moving masses below 700 g with powerful antagonistic compliant actuation with pneumatic artificial muscles. Rather than recreating human anatomy, our system is designed to be easy to control in order to facilitate future learning of fast trajectory tracking control. The resulting robot is precise at low speeds using a simple PID controller while reaching high velocities of up to 12 m/s in task space and 1500 dig/s in joint space. This arm will enable new applications in fast changing and uncertain task like robot table tennis while being a sophisticated and reproducible test-bed for robot skill learning methods. Construction details are available.

I. INTRODUCTION

An intended outcome of robotics research is to make robots help humanity by taking over simple work. This is already achieved for industrial applications like pick-and-place tasks where robots move along a predefined and henceforth unchanged trajectory. However, when it comes to uncertain, high-dimensional and fast-changing tasks, e.g. walking and running for humanoid robots (see Darpa Robotics Challenge [8]) or playing table tennis with an anthropomorphic arm [19], robots are not able to reach the performance of humans. The explanation lies in the interplay between control algorithms that cannot fully use the potential of the given system and the robot hardware design that makes control of versatile movements problematic. The human arm design owns many beneficial properties that widen the range of possible trajectories, thus enrich the variety of tasks being able to fulfill. For instance, it enables to lift heavy objects and generate high accelerations at the end-effector. Hence high velocities can be reached over a small distance which enables fast reaction times. Concurrently, the human arm is robust due to the soft skin, inhibiting damage at collisions and the built-in passive compliance which ensures the deflection of the end-effector instead of breakage as a response to external forces. Robustness against errors in control is an additional benefit of compliance e.g. for grasping, moving objects (fitting objects into a tight form) or for fast changing tasks where full precision cannot be achieved like in table tennis.

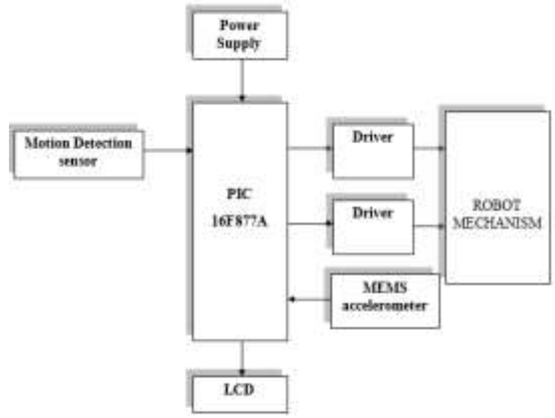
II. HARDWARE CONFIGURATION

Pneumatic actuators, usually cylinders, are widely used in factory floor automation. Lately, robotics as well is starting to use

Vol 10, Issue 12, DEC/2019
ISSN NO:0377-9254

pneumatics as a main motion power source. One of the major attractions about pneumatics is the low weight and the inherent compliant behavior of its actuators. Compliance is due to the compressibility of air and, as such, can be influenced by controlling the operating pressure. This is an important feature whenever there is an interaction between man and machine or when delicate operations have to be carried out (e.g. handling of fragile objects). Thanks to compliance a soft touch and safe interaction can be easily guaranteed. Hydraulic and electric drives, in contrast, have a very rigid behavior and can only be made to act in a compliant manner through the use of relatively complex feedback control strategies. Several types of pneumatic actuators—e.g. cylinders, bellows, pneumatic engines and even pneumatic stepper motors—are commonly used to date. A less well-known type is that of the so-called Pneumatic Artificial Muscles (PAMs).

These are in fact inverse bellows, i.e. they contract on inflation. Their force is not only dependent on pressure but also on their state of inflation, which makes for a second source of spring-like behavior. They are extremely lightweight because their core element is but a membrane, and yet, they can transfer the same amount of energy as cylinders do, since they operate at the same pressure ranges and volumes. For these reasons they carry a great potential to be used to power mobile robots, where they have additional advantages, such as direct connection, easy replacement and safe operation, as will be seen later.



A) POWER SUPPLY

The power supply section is the section which provide +5V for the components to work. IC LM7805 is used for providing a constant power of +5V. The ac voltage, typically 220V, is connected to a transformer, which steps down that ac voltage down to the level of the desired dc output. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simple capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or ac voltage variation. A regulator circuit removes the ripples and also retains the same dc value even if the input dc voltage varies, or the load connected to the output dc voltage changes. This voltage regulation is usually obtained using one of the popular voltage regulator IC units.

B) OVERVIEW OF PIC 16F877

PIC 16F877 is one of the most advanced microcontrollers from Microchip. This controller is widely used for experimental and modern applications because of its low price, wide range of applications, high quality, and ease of availability. It is ideal for applications such as machine control applications, measurement devices, study purpose, and so on. The PIC 16F877 features all the components which modern microcontrollers normally have. The figure of a PIC16F877 chip is shown below.

FEATURES OF PIC16F877

The PIC16FXX series has more advanced and developed features when compared to its previous series. The important features of PIC16F877 series is given below.

Fig: PIC Microcontroller

GENERAL FEATURES:

- High performance RISC CPU.
- ONLY 35 simple word instructions.
- All single cycle instructions except for program branches which are two cycles.
- Operating speed: clock input (200MHz), instruction cycle (200nS).
- Up to 368×8bit of RAM (data memory), 256×8 of EEPROM (data memory), 8k×14 of flash memory.
- Eight level deep hardware stack.
- Interrupt capability (up to 14 sources).
- Different types of addressing modes (direct, Indirect, relative addressing modes).
- Power on Reset (POR).
- Power-Up Timer (PWRT) and oscillator start-up timer.
- Low power- high speed CMOS flash/EEPROM.
- Fully static design.
- Wide operating voltage range (2.0 – 5.56) volts.
- High sink/source current (25mA).
- Commercial, industrial and extended temperature ranges.
- Low power consumption (<0.6mA typical @3v-4MHz, 20µA typical @3v-32MHz and <1 A typical standby).

PERIPHERAL FEATURES:

- Timer 0: 8-bit timer/counter with pre-scalar.
- Timer 1:16 bit timer/counter with pre-scalar.
- Timer 2: 8 bit timer/counter with 8 bit period registers with pre-scalar and post-scalar.
- Two Capture (16bit/12.5nS), Compare (16 bit/200nS), Pulse Width Modules (10bit).
- 10bit multi-channel A/D converter
- Synchronous Serial Port (SSP) with SPI (master code) and I2C (master/slave).
- Universal Synchronous Asynchronous Receiver Transmitter (USART) with 9 bit address detection.
- Parallel Slave Port (PSP) 8 bit wide with external RD, WR and CS controls (40/46pin).
- Brown Out circuitry for Brown-Out Reset (BOR).

KEY FEATURES:

- Maximum operating frequency is 20MHz.
- Flash program memory (14 bit words), 8KB.
- Data memory (bytes) is 368.
- EEPROM data memory (bytes) is 256.
- 5 input/output ports.
- 3 timers.
- 2 CCP modules.
- 2 serial communication ports (MSSP, USART).
- PSP parallel communication port
- 10bit A/D module (8 channels)

ANALOG FEATURES:

- 10bit, up to 8 channel A/D converter.
- Brown Out Reset function.
- Analog comparator module.

SPECIAL FEATURES:

- 100000 times erase/write cycle enhanced memory.
- 1000000 times erase/write cycle data EEPROM memory.
- Self-programmable under software control.

Vol 10, Issue 12, DEC/2019
ISSN NO:0377-9254

- In-circuit serial programming and in-circuit debugging capability.
- Single 5V,DC supply for circuit serial programming
- WDT with its own RC oscillator for reliable operation.
- Programmable code protection.
- Power saving sleep modes.
- Selectable oscillator options.

C) MEMS SENSOR

An accelerometer is a micro-electromechanical device that measures acceleration forces. These forces may be static, like the constant force of gravity pulling at our feet, or they could be dynamic - caused by moving or vibrating the accelerometer. There are many types of accelerometers developed and reported in the literature. The vast majority is based on piezoelectric crystals, but they are too big and too clumsy. People tried to develop something smaller, that could increase applicability and started searching in the field of microelectronics. They developed MEMS (micro electromechanical systems) accelerometers.

MEMS SENSOR

MEMS accelerometer use nanotechnology in order to enhance the natural abilities common between all accelerators; hence, these devices are extremely fine-tuned and accurate. MEMS stands for Micro Electro Mechanical Systems, and when discussing the technicalities of accelerometers it refers specifically to a mass-displacer that can translate external forces such as gravity into kinetic motion energy. This part of the accelerometer usually contains some type of spring force in order to balance the external pressure and displace its mass, thus leading to the motion that produces acceleration.

Features

- 3-axis single-chip accelerometer
- Built-in IC integrating temperature sensor and self-diagnosis function
- High sensitivity: up to 1,000 mV/G
- Automatic correction of mounting angle
- Small size: 5.0 x 5.0 x 2.3mm
- Inertial sensing (linear, angular) in small, PCB-capable packaging
- Reliable operation
- Low power dissipation
- Cost effective
- Simple Integration

D) LIQUID CRYSTAL DISPLAY (LCD)

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on. A **16x2 LCD** means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data.

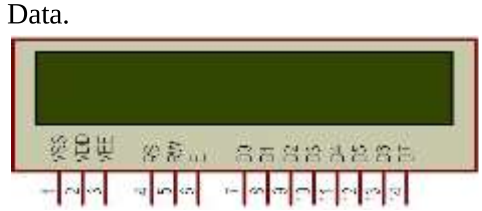


Fig. 16x2 LCD

The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data

JES Journal of Engineering Sciences
Vol 10, Issue 12, DEC/2019
ISSN NO:0377-9254

register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.

E) DRIVER CIRCUIT (L293D)

L293D IC generally comes as a standard 16-pin DIP (dual-in line package). This motor driver IC can simultaneously control two small motors in either direction; forward and reverse with just 4 microcontroller pins (if you do not use enable pins).

Description

It works on the concept of H-bridge. H-bridge is a circuit which allows the voltage to be flown in either direction. As you know voltage need to change its direction for being able to rotate the motor in clockwise or anticlockwise direction, hence H-bridge IC are ideal for driving a DC motor. In a single l293d chip there two h-Bridge circuit inside the IC which can rotate two dc motor independently. Due its size it is very much used in robotic application for controlling DC motors.

Pin Diagram

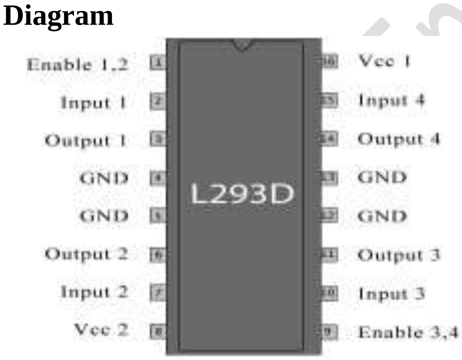


Fig showing pin diagram of L293D

Given below is the pin diagram of a L293D motor controller. There are two Enable pins on l293d. Pin 1 and pin 9, for being able to drive the motor, the pin 1 and 9 need to be high. For driving the motor with left H-bridge you need to enable pin 1 to high. And for right H-Bridge you need to make the pin 9 to high. If anyone of the either pin1 or pin9 goes low then the motor in the corresponding section will suspend working. It's like a switch.

F) DC MOTOR

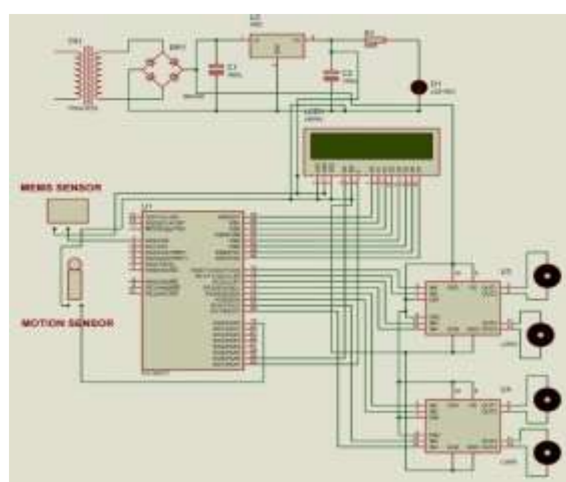
A DC motor in simple words is a device that converts direct current (electrical energy) into mechanical energy. It's of vital importance for the industry today.

A DC motor is designed to run on DC electric power. Two examples of pure DC designs are Michael Faraday's homo-polar motor (which is uncommon), and the ball bearing motor, which is (so far) a novelty.

By far the most common DC motor types are the brushed and brushless types, which use internal and external commutation respectively to create an oscillating AC current from the DC source—so they are not purely DC machines in a strict sense. We in our project are using brushed DC Motor, which will operate in the ratings of 12v DC 0.6A.

The speed of a DC motor can be controlled by changing the voltage applied to the armature or by changing the field current. The introduction of variable resistance in the armature circuit or field circuit allowed speed control. Modern DC motors are often controlled by power electronics systems called DC drives.

III SCHEMATIC DIAGRAM



IV. RESULTS & FEATURE SCOPE

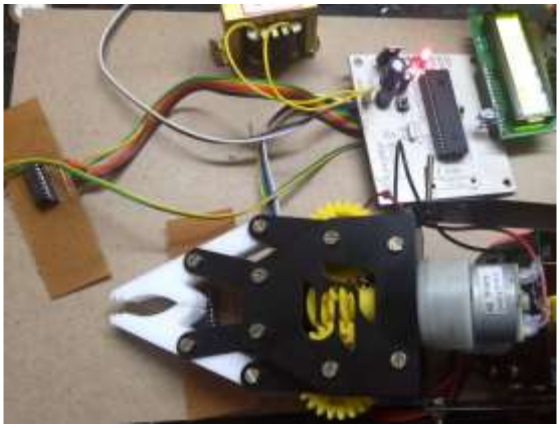


Fig Hardware Setup

Fig LCD Display

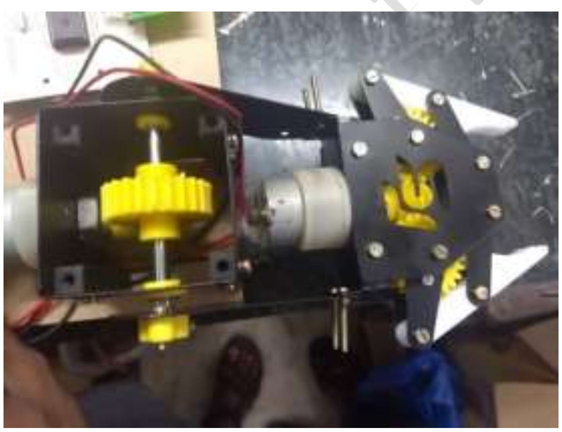


Fig Robotic ARM Open Condition

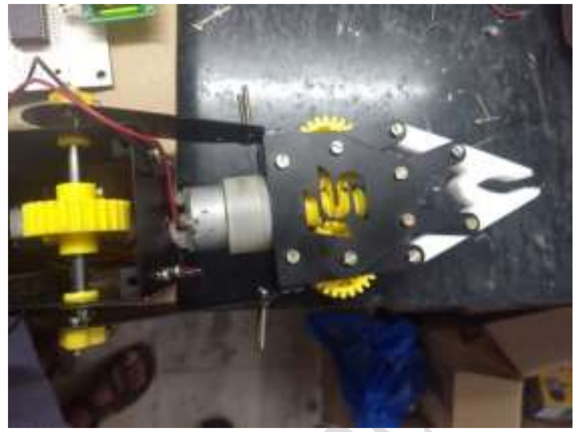


Fig. Robotic ARM Closed Condition

V. FUTURE WORK

Taking humans as an example of successful systems that are able to overcome the non-linearity's, task uncertainty and high-dimensionality of the human motor system, learning control is a promising direction. Experiments provide Compelling evidence for the employment of Reinforcement Learning (RL) in the human sensorimotor learning system in particular, model-based RL which is known for its high sample efficiency. relies on precise internal models. Involvement of forward models in human motor learning can be verified on the behavioral level [11].

VI. REFERENCES

[1] Kyoung Kwan Ahn and Ho Pham Huy Anh. Design and implementation of an adaptive recurrent neural networks (ARNN) controller of the pneumatic artificial muscle (PAM) manipulator. Mechatronics, 19(6):816–828, September 2009.

[2] G. Andrikopoulos, G. Nikolakopoulos, I Arvanitakis, and S. Manesis. Piecewise Affine Modeling and Constrained Optimal Control for a Pneumatic Artificial Muscle. IEEE Transactions on Industrial Electronics, 61(2):904–916, February 2014.

[3] Ivo Boblan, Rudolf Bannasch, Hartmut Schwenk, Frank Prietzel, Lars Miertsch, and

Andreas Schulz. A Human-Like Robot Hand and Arm with Fluidic Muscles: Biologically Inspired Construction and Functionality. In Fumiya Iida, Rolf Pfeifer, Luc Steels, and Yasuo Kuniyoshi, editors, Embodied Artificial Intelligence, number 3139 in Lecture Notes in Computer Science, pages 160–179. Springer Berlin Heidelberg, January 2004.

[4] Darwin G. Caldwell, Gustavo A. Medrano-Cerda, and Mike Goodwin. Control of pneumatic muscle actuators. Control Systems, IEEE, 15(1):40–48, 1995.

[5] D.G. Caldwell, N. Tsagarakis, D. Badihi, and G.A. Medrano-Cerda. Pneumatic muscle actuator technology: a light weight power system for a humanoid robot. In 1998 IEEE International Conference on Robotics and Automation, 1998. Proceedings, volume 4, pages 3053– 3058 vol.4, 1998.

[6] Ching-Ping Chou and B. Hannaford. Measurement and modeling of McKibben pneumatic artificial muscles. IEEE Transactions on Robotics and Automation, 12(1):90–102, 1996.

[7] Ching-Ping Chou and Blake Hannaford. Static and dynamic characteristics of McKibben pneumatic artificial muscles. In Robotics and Automation, 1994. Proceedings. 1994 IEEE International Conference on, pages 281–286. IEEE, 1994.

[8] Darpa. Darpa Robotics Challenge, 2015.

[9] Marc Peter Deisenroth, Gerhard Neumann, and Jan Peters. A Survey on Policy Search for Robotics. 2013.

[10] Festo. Airics arm. 2007. http://www.festo.com/rep/de corp/assets/pdf/Airics arm de.pdf

[11] Adrian M. Haith and John W. Krakauer. Model-Based and Model-Free Mechanisms of Human Motor Learning. In Michael J. Richardson, Michael A. Riley, and Kevin Shockley, editors, Progress in Motor Control, number 782 in Advances in Experimental Medicine and Biology, pages 1–21. Springer New York, January 2013.

[12] Christoph Hartmann, Joschka Boedecker, Oliver Obst, Shuhei Ikemoto, and Minoru Asada. Real-Time Inverse Dynamics Learning for Musculoskeletal Robots based on Echo State Gaussian Process Regression. In Robotics: Science and Systems, 2012.

[13] A. Hildebrandt, O. Sawodny, R. Neumann, and A. Hartmann. Cascaded control concept of a robot with two degrees of freedom driven by four artificial pneumatic muscle actuators. In American Control Conference, 2005. Proceedings of the 2005, pages 680–685 vol. 1, 2005.

[14] Igus. Robolink light-weight robotic arm. 2015. http://www.igus.de/contentData/wpck/pdf/global /EN robolink- Info s.pdf

[15] S. Ikemoto, Y. Nishigori, and K. Hosoda. Direct teaching method for musculoskeletal robots driven by pneumatic artificial muscles. In 2012 IEEE International Conference on Robotics and Automation (ICRA), pages 3185–3191, May 2012.

[16] G.K. Klute, J.M. Czerniecki, and B. Hannaford. McKibben artificial muscles: pneumatic actuators with biomechanical intelligence. In 1999 IEEE/ASME International Conference on Advanced Intelligent Mechatronics, 1999. Proceedings, pages 221–226, 1999.