

Design and Control of 3-DOF Articulated Robotic Arm using LabVIEW and NI-myRIO

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Abstract: This paper focus on designing and controlling an articulated 3-DOF robotic arm using LabVIEW and NI-myRIO. Nowadays Robots have been used in common places of manufacturing and making the tasks ranging complicated and expensive to be automated, since technology formulates LabVIEW is used to make the robot more precise and practical along with a hardware NI-myRIO. The three base, axis and wrist movements are obtained by using stepper motor and 2 DC gear motor. NI-myRIO is used to generate and acquire signals for controlling and processing, it has an inbuilt processor and FPGA and has many reconfigurable analog and digital pins.

Keywords: LabVIEW, NI-myRIO, DOF, Robotic arm, Stepper motor

1. INTRODUCTION

Robot is a machine to execute different task repeatedly with high accuracy. Thereby many functions like collecting information and studies about the hazardous sites which is too risky to send human inside. Robots are used to reduce the human interference nearly 50 percent. Robots are used in different types like fire fighting robot, metal detecting robot, etc.

Robots are defined by the nature of their movement. There are five important classifications of robots. They are described as follows

- Cartesian
- Cylindrical
- Polar
- Articulated
- SCARA

The first robotic arm to be used in an automobile industry was “UNIMATE” in GM motors USA in 1950s. From then there has been enormous improvement in the research and development in robotics. Now robots are an integral part of almost all industries. Robots have to do different tasks including welding, trimming, picking and placing etc. These robots are controlled in different ways like keypads, voice control, etc.

Our paper portraits the control of an 3-DOF robotic arm using LabVIEW and NI-myRIO which makes the system more precise and reduces time delay and it is comparatively better than other programming languages in the field of monitoring and control.

2. HARDWARE

2.1. Articulated robot:

An articulated robot is a robot which is fitted with rotary joints. Rotary joints allow a full range of motion, as they rotate through multiple planes, and they increase the capabilities of the robot considerably. An articulated robot can have one or more rotary joints, and other types of joints may be used as well, depending on the design of the robot and its intended function. With rotary joints, a robot can engage in very exact movements. Articulated robots commonly show up on manufacturing lines, where they

utilize their flexibility to bend in a variety of directions. Multiple arms can be used for greater control or to conduct multiple tasks at once, for example, and rotary joints allow robots to do things like turning back and forth between different work areas.

These robots can also be seen at work in labs and in numerous other settings. Researchers developing robots often work with articulated robots when they want to engage in activities like teaching robots to walk and developing robotic arms. The joints in the robot can be programmed to interact with each other in addition to activating independently, allowing the robot to have an even higher degree of control. Many next generation robots are articulated because this allows for a high level of functionality.

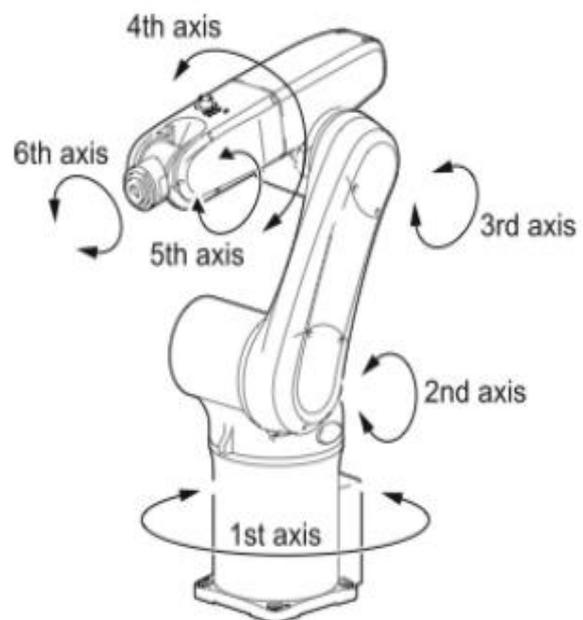


Figure 1: Model of Articulated robotic arm

2.2. Stepper Motor:

Stepper motor also called Step motor in which single rotation is fragmented into several steps. These motors are primarily used in measurement and control applications. The commutator and brushes of conventional motor are some of the most failure inclined components and they create electrical arcs that are undesirable or dangerous in some environments. Stepper motors are brushless and it is an electromechanical device which converts electrical pulses into discrete mechanical movements. The shaft or spindle of a stepper motor rotates in discrete step increments, when electrical command pulses are applied to it in the proper sequence. Stepper Motors come in a variety of sizes, and strengths, from tiny floppy disk motors, to huge machinery steppers.

There are two basic types of stepper motors, bipolar and unipolar. The motor which is used in this paper is a unipolar stepper motor. A unipolar stepper motor is really two motors sandwiched together. Each motor is composed of two windings. Wires connect to each of the four windings of the motor pair, so there are eight wires coming from the motor. The commons from the windings are often ganged together, which reduces the wire count to five or six instead of eight. We have used unipolar motor. It has 6 leads.

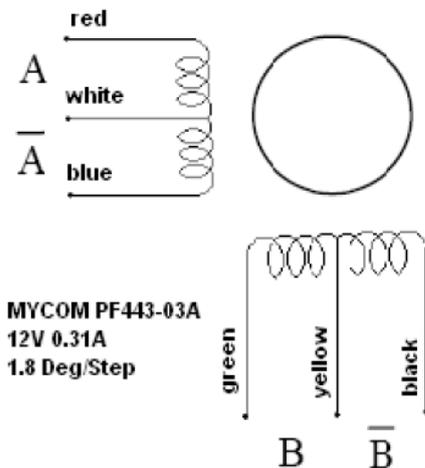


Figure 2: Circuit diagram of unipolar stepper motor

Its specifications are given below

Voltage: 12V

Current: 1A

Step angle: 1.8°

2.2.1. Step modes:

Stepper motor drivers often have different modes of operation. These different modes determine in what sequence the coils are energized to make the motor shaft move appropriately. There are four types of these stepping modes. However, only three of the excitation modes are common in most stepper drivers.

2.2.1.1. Full Step:

This method of stepping the motor energizes both phases constantly to achieve full rated torque at all positions of the motor. If a stepper motor has 200 steps, one pulse

equals one step. So, 200 pulses from the NC computer results in 360 degrees of motor shaft rotation. A uni-polar stepper motor driver operating in full step mode energizes a single phase. A bipolar stepper motor driver energizes both coils to make a full step. The first image is single coil full step operation while the second is dual core full step mode.

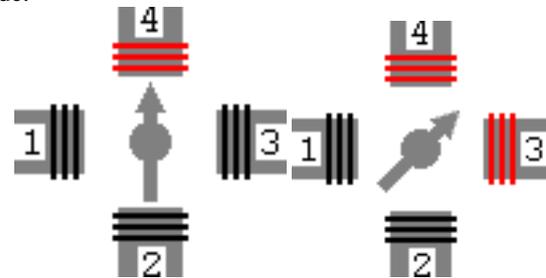


Figure 3: Full step mode operation

2.2.1.2. Half Step:

The Half step mode energizes a single coil then two coils then one again. Alternating between energizing a single phase and both phases together gives the motor its higher resolution. A 200 step stepper motor operating in half step mode would have 400 positions, twice the normal resolution. However, the torque will vary depending on the step position because at times a single phase will be energized while at other times both phases will be energized. Higher end drivers compensate by increasing the current through the single coil when a single coil is energized. This makes up for the loss in torque, making the half step mode very stable.

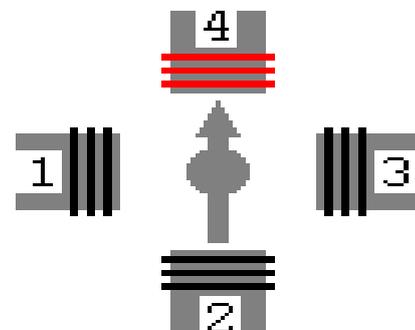


Figure 4: Half step mode operation

2.2.1.3. Micro-stepping:

The micro-stepping mode is the most complex of all the stepping modes. That is why some stepper drivers only offer full and half step modes. Micro-stepping is when the current applied to each winding is proportional to a mathematical function, providing a fraction of a full step. The most common divisions are 1/4th, 1/8th, 1/10th, etc. However, there are some drivers that provide up to 1/256th of a full step.

Micro-stepping provides greater resolution and smoother motor operation. This is very advantageous as it reduces the need for mechanical gearing when trying to achieve high resolution. However, micro-stepping can affect the repeatability of the motor. We have used micro step for smooth operation.

Steps	A	B	C	D
0	ON	OFF	OFF	OFF
1	OFF	ON	OFF	OFF
2	OFF	OFF	ON	OFF
3	OFF	OFF	OFF	ON

Figure 5: Wave drive mode truth table

2.3. DC GEAR MOTOR:

DC motor converts electrical power to mechanical force. Geared DC motor are little bit extension of DC motor, they consist of a shaft and a gear arrangement. The speed of the gear motor is counted in terms of rotation in shaft per minute and is termed as RPM.

The gear assembly helps in increasing the torque so that it can lift weights and decreases speed. Here we are using 2-DC gear motors for elbow and arm movement. The following figure shows the diagram of a DC gear motor.

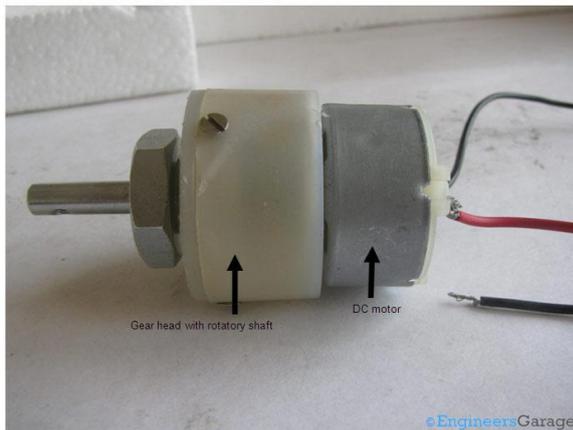


Figure 6: DC gear motor

2.4. NI-myRIO:

It is a hardware developed by National Instruments, Texas used to acquire and process real time signals. It is a portable reconfigurable input / output abbreviated as RIO. It consists of a processor and FPGA embedded in it and it is compact.

It consists of two expansion port (MXP) connectors A and B carry identical set of signals and both have 34 pin outs and a mini system port (MSP) called Connector C. In both the cases there are certain pins which carry primary and secondary functions.

Signals can be acquired and processed in LabVIEW and the generated signals can be used in real time. NI-myRIO has 3.3v, 5v, +/- 15v power output.

It provides connectivity with the host computer either over USB or wireless connectivity. It has an inbuilt accelerometer and special functions like Pulse width modulation, UART, Audio input and output terminals.



Figure 7: NI-myRIO Kit

2.5. MOTOR DRIVER CIRCUIT:

The driver circuit consists of Dual H Bridge. H Bridge enables a voltage to be applied in either direction for a motor. This H Bridge powers the motor.

It can be used for reversing the polarity and braking of the motor. This circuit is connected with the required voltage of 12 volts to power the motor. The triggering is given by the myRIO digital output port. Digital output port generates 3.3V as triggering pulse. The following figure shows the schematic diagram of L293D motor driver circuit.

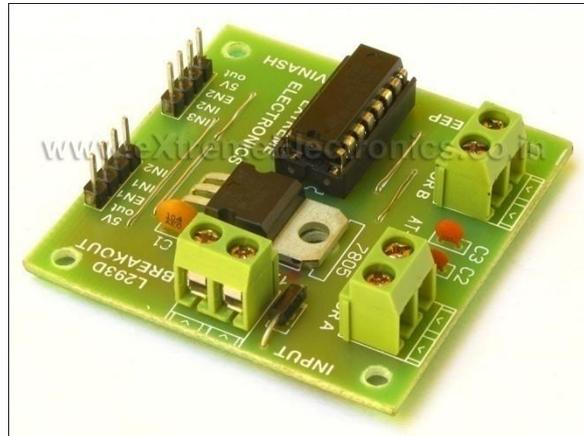


Figure 8: L293D motor driver circuit

3. DEGREE OF FREEDOM

In statistics, the number of degrees of freedom is the number of values in the final calculation of a statistic that are free to vary. The number of independent ways by which a dynamic system can move, without violating any constraint imposed on it, is called number of degrees of freedom. In other words, the number of degree of freedom can be defined as the minimum number of independent coordinates that can specify the position of the system completely. Estimates of statistical parameters can be based upon different amounts of information or data. The number of independent pieces of information that go into the estimate of a parameter is called the degrees of freedom. In general, the degrees of freedom of an estimate of a parameter is equal to the number of independent

scores that go into the estimate minus the number of parameters used as intermediate steps in the estimation of the parameter itself (i.e. the sample variance has $N-1$ degrees of freedom, since it is computed from N random scores minus the only 1 parameter estimated as intermediate step, which is the sample mean).

Mathematically, degrees of freedom is the number of dimensions of the domain of a random vector, or essentially the number of "free" components (how many components need to be known before the vector is fully determined). Here we used three DOF.

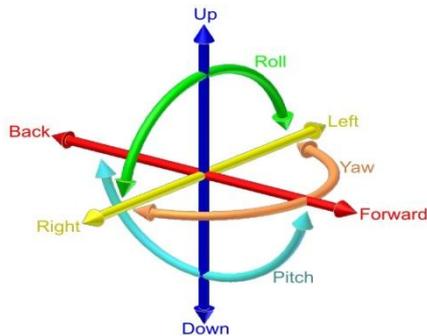


Figure 9: Positions of Degree of freedom

4. LabVIEW

Laboratory Virtual Instrumentation Work Bench abbreviated as LabVIEW is a Virtual programming language. LabVIEW is a highly productive, development environment for creating custom application that interact with the real world signals in fields such as science and engineering. LabVIEW is unique because it makes this wide variety of tools available in single environment. LabVIEW is a development environment for problem solving leading to accelerated productivity and continual innovation. G-Programming being a central tool in LabVIEW has been widely used to interlink data acquisition, analysis and logic operations. It is a high level data flow graphical programming language designed to develop application that are interactive, executing in parallel and multi-core.

It is commonly used for industrial monitoring, control and Automation. Programming is done using 3 panels as follows front panel, Block diagram and connector panel, where front panel serve as user interface where controls and indicators are placed and monitoring is carried out, Block diagram consists of functional blocks in which inputs are been wired and connector panel is used to generate sub VI's. Compared to other programming languages LabVIEW is user friendly because programming is done by picking and placing blocks rather than typing a lengthy code and error correction is very easy.

5. EXPERIMENTAL SETUP:

The following figure shows the real time setup of control of 3-DOF robotic arm using LabVIEW and NI-myRIO.



Figure 10: Experimental Setup

6. INTERFACING

The software used for the project is LabVIEW, version 2014. We have configured our program in such a manner that the RIO powers the driver circuit. myRIO can only give a digital pulse of 3.3 volts not more than that, so we have utilized this digital pulse to trigger the driver circuit so that it will route the 12 volts connected to it to drive the stepper motor and 2-DC gear motor. We have programmed the motor to run in both forward and in reverse direction too. By introducing a time delay we have also controlled the speed of the base stepper motor.

For the stepper motor Forward direction in a particular sequence the digital output comes from the sequence structure and similarly in the opposite direction the sequence is given in the reverse order, for which Enum, case structures and while loop has been utilized. The four windings of the motor are assigned separate cases of Enum. The wires to be triggered in case of forward movement are in the following sequence-red, green, orange and blue. For reverse direction it should be powered in the opposite direction. In case of DC motor just two pulses are enough to trigger it both in forward and reverse direction.

7. SIMULATION AND RESULTS:

The following figure shows the front panel and block diagram of the control Vi.

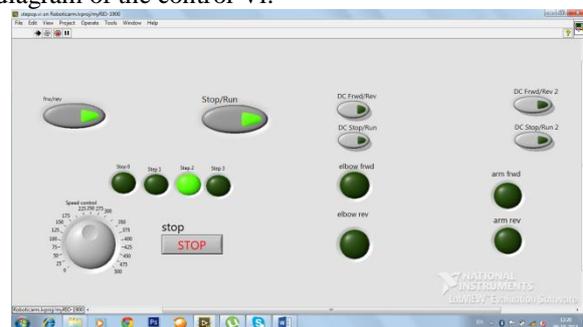


Figure 11: Front panel of control.vi

By using shift registers and case structures we have given the sequence in which the motor must run in case of forward and reverse directions, so that it moves in the required direction accordingly. The usage of while loop along with case structure with shift registers and enum is called as a **State machine architecture** in LabVIEW.

The front panel consists of LED's that indicate the direction of the motor, sequence of the powering of

windings, and a dial for the speed control of the stepper motor. As the time delay increases the speed of the stepper motor decreases and vice-versa. By the same way the movement of elbow and arm is also denoted by Boolean LED's and it is programmed as an open loop system i.e operated manually it is programmed in a way that only one movement can be done at a time with the help of select switches.

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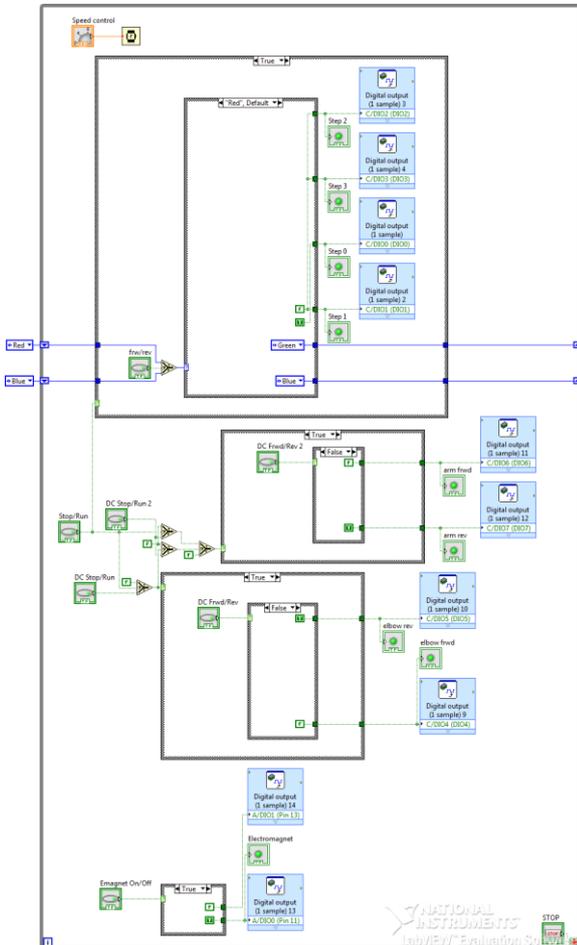


Figure 12: Block diagram of control.vi

8. CONCLUSION

Thus the control of 3-DOF robotic arm has been implemented successfully using LabVIEW and my-RIO. The effectiveness of the project can be put to profitable use in any in any kind of environment that doesn't require or forbade the involvement of humans like in hazardous environments, mining, and many such industrial, medical fields. Its application can thus be extended to any field with changes in the end effectors and can be used for many diverse applications.

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