International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-1, November 2019

Design and Development of Z-Robot for industrial Applications

J. Indra, R. Kiruba Shankar, N. Ilakkiya, S. Indujha, S. Guhan

Abstract: The last few decades have demonstrated the benefit of fast, vast and inexpensive robots in production sectors. Robots in the industry can be cooperative or supportive to the workers. Some significant tasks such as, industrial automation, painting, welding, package loading and unloading, cutting and application specific tasks can be performed using industrial robotic arm. The aim of the project is to pick and place the objects in industries using robot arms. Z-Robot is a double arm robot. The robot arms follow the loop in a program to run the servo motors. Arduino program stores the position of each motor. When the pick command is received servo motors fixed with the robot arms start rotating based on the program and picks up the object. When the drop command is received the robot arms drops down the object. The pick and place operations can be done in any direction. End effectors connected with arm setup is used to pick and place the object.

Keywords: robot, arm, pick and place

I. INTRODUCTION

Robotic arm is most commonly manufactured nowadays. Generally it is constructed using seven metal segments, which in turn are joined by six joints. A computer can monitor and control the entire operation of robot by employing separate stepper motors that are connected to each joint. Stepper motors operate with exact increments unlike other motors. Since the same movement is exactly repeated, the arm movement is very precise and is done by the computer. The robot employs motion sensors to ensure that it moves in correct steps.

A. Existing Methodology

Robots in industries are almost similar to human beings; they possess the equivalent of a shoulder, an elbow and a wrist [1]. Generally, the shoulder is mounted on a fixed base structure rather than a movable one.

Revised Manuscript Received on November 30, 2019.
* Correspondence Author

J.Indra*, Associate Professor, Department of Electronics and Instrumentation Engineering, Kongu Engineering College, Perundurai, Erode, Tamilnadu, India. Email: indrajaganathan@gmail.com

R.Kirubashankar, Associate Professor, Department of Mechatronics Engineering, Kongu Engineering College, Perundurai, Erode.

N. Ilakkiya, Department of Electronics and Instrumentation Engineering, Kongu Engineering College, Perundurai

S.Indujha, B.E. Electronics and Instrumentation Engineering at Kongu Engineering College, Perundurai, Erode.

S.Guhan, B.E. Electronics and Instrumentation Engineering at Kongu Engineering College, Perundurai, Erode.

The robotic arm moves the end effectors. The user can equip the arms of the robot with any type of end effectors suitable for the required application [2]. One familiar end effector is the basic version of the hand that can grab and carry different objects. Most of the robotic hands have built-in pressure sensors that report the hardness of gripping a particular object. This prevents the robot from dropping or breaking anything that it carries.

Other end effectors include blowtorches, drills and spray painters.

Disadvantages of Existing Method

- The industrial robot arm cannot be programmed by normal labors and only a skilled programmer can program the robot arm.
- The end effectors are generally made up of metals which will damage the handling of light weight objects.

B. Proposed Methodology

The 4-axis robot arm with non-metallic end effectors is controlled by Arduino coding. This robot picks the object and places it on the other side. It can also move in any direction. After a reset, the robot arm follows the command given by the user according to the coded program to run the servo motors and the DC motors. Arduino program stores the position of each motor. When the pick command is received servo motors fixed with the robot arm and end effectors picks up the object. When the drop command is received the robot drops down the object and returns to its original position based on the users command.

Advantages of Proposed Method

- Easily programmable and reprogrammable.
- Reduces the man power and also human error in industries.

II. COMPONENTS AND DESCRIPTION

A. Arduino Board

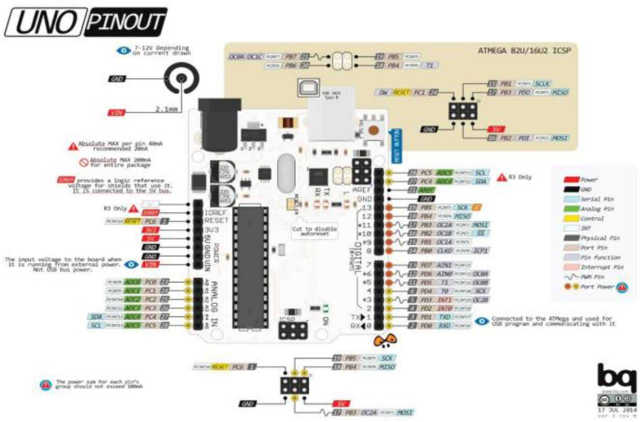

Fig. 1. Arduino Block Diagram

A.1 Power USB
Arduino board shown in fig.1 can be powered by using the USB cable from the computer. Its supply level voltage is 5V [6].

A.2 Power (Barrel Jack)
Arduino boards are operated from the power supply by connecting via the Barrel Jack.

A.3 Voltage Regulator
Voltage regulator controls the voltage supplied to the Arduino and stabilizes the DC voltages which are utilized by the processor and other elements. Voltage levels range from 3.3V or 5V.

A.4 Crystal Oscillator
The crystal oscillator has a frequency of 16MHz.

A.5 Arduino Reset
UNO board can be reset by using the reset switch on board or by external reset.Supply pins are (3.3, 5, GND, Vin). Vin pin is used to externally power the Arduino board.

A.6 Analog Pins
A0 to A5 are the six analog input pins. These pins can accept the analog signals from sensors like humidity/temperature sensors and convert it into digital output that is fed to the processor / controller [8] .

A.7 Main Microcontroller
Most of the arduino boards have atmega controllers as their brain. But it differs for different boards. In general ATMEL company controllers are preferred.

A.8 ICSP Pin
Typically, ICSP is an AVR, a small programming header for Arduino which includes MOSI, MISO, SCK, RESET, VCC, and GND[7]. It is actually referred as SPI (Serial Peripheral Interface), which is seen as an "expansion" of the output. In general they slave the output device to the master of the SPI bus.

A.9 Power LED Indicator
This LED indicates that arduino is powered up correctly when that is plugged into a power source. If this light does not glow, it indicates incorrect connection.

A.10 TX and RX LEDs
The two pins TX and RX serve for the serial data communication. The data can be transmitted at different baud rates through the TX pin and the RX pins serves for receiving the serial data. The respective LEDs glow during this process.

A.11 Digital I/O
There are 14 digital I/O pins, out of which PWM output is possible through 6 pins. These pins are configured to function as digital input pins to read logic values (0 or 1) or as digital output to drive different modules like LEDs, relays, etc.

A.12 AREF
AREF specifies Analog Reference. Sometimes external reference voltage can also be set in the range of 0 to 5 volts, which can serve as the upper limit for analog pins at the input.

B. Stepper Motor
The stepper motor shown in fig.2 is a brushless DC electric motor which splits a full rotation into a number of equal steps. The motor's position can be controlled to move and remain at one of these steps devoid of any position sensor for feedback, provided that the motor is cautiously sized to the application considering the torque and speed [3].
The stepper motor converts a train of input pulses into exactly defined increments along the shaft position. Each pulse is capable of moving the shaft through a fixed angle [4].

Fig. 2. Stepper Motor

Stepper motors include multiple "toothed" electromagnets set around a central gear-shaped piece of iron. An external driver circuit or a microcontroller powers the electromagnets. When the electromagnets gain power, they attract the gear's teeth and in turn make the motor to run. Once the gear's teeth are aligned to the first electromagnet, they are a little offset from the next electromagnet [5]. This procedure continues for the next electromagnet and so on.. Likewise this process is made repetitive. Each of those rotations is termed as a "step", with an integer number of steps creating a full rotation. In this way, the motor rotates by a precise angle.
When the full rated current is reached during each step, the torque is maximum. The variation in the drive current is due to winding inductance and counter-EMF generated by the moving rotor. So when the motor gains speed, less time is spent at full current and thus decreases the motor torque. As speed rises further, the current cannot reach the rated value, and in due course the motor will stop producing the torque.
The benefits of stepper motor are low cost, high reliability, high torque at low speeds and a simple, rugged construction which can work in any environment. But the demerit in employing a stepper motor is the resonance effect that is regularly found at low speeds and the reducing torque with growing speed.

C. DC Motor

A DC motor shown in fig. 3 converts electrical energy to mechanical energy. The most familiar types depend on the forces generated by magnetic fields. Mostly all the DC motors have either electromechanical or electronic mechanism, to sporadically change the direction of current flow in the motor.

Retrieval Number: K22910981119/2019©BEIESP
DOI: 10.35940/ijitee.K2291.119119
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

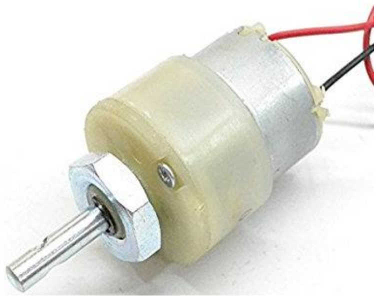

Fig. 3. DC Motor

The speed of the DC motor can be varied over a wide range, by employing a variable supply voltage or by varying the strength of current in its field windings. Small DC motors are useful n tools, toys, and appliances. The universal motor can work with direct current. It is a lightweight brushed motor employed for handy power tools and appliances. Larger DC motors are useful for electric vehicles propulsion, elevator and hoists, and also in drives for steel rolling mills.

A simple DC motor has a fixed set of magnets in the stator and an armature with one or more windings of insulated wire wound around a soft iron core which constitutes for the magnetic field. The windings usually have multiple turns around the core, and in large motors there can be a number of parallel current paths. The winding ends are joined to a commutator. This permits each armature coil to be energized in turn and connects the rotating coils with the external power supply via brushes.

A series DC motor has the armature and field windings connected in series with a common D.C. power supply. The speed of the motor varies non-linearly with respect to load torque and armature current; current is common to both the stator and rotor which yields current squared behavior. The starting torque in series motor is very high and it is employed in trains, elevators or hoists.[2] This speed/torque feature is helpful in applications such as dragline excavators, where the digging tool has to move quickly during unloaded conditions and slow down when carrying a heavy load.

A series motor must never be started at no load. Because at no load, current is less, the field winding produces a weak counter-electro motive force and hence the armature must rotate faster to produce sufficient counter-EMF to stabilize the supply voltage. As a result over speed can damage the motor.

D. 5V Relay Module

Fig.4. 5V Four Channel Relay Module

A 5V 4-channel relay shown in fig.4. Each channel requires a 15-20mA driver current. It can be employed to control different appliances and equipment with high current. It has a standard interface that can be controlled through a microcontroller directly.

When the signal port is at low level, the signal light powers up and the optocoupler 817c conducts. The transistor then conducts making the relay coil to be electrified, and the normally open contact of the relay is closed. When the signal is high, the normally closed contact of the relay is closed. So the load is connected and disconnected by controlling the signal levels.

E. End Effector

In robots, the end effector is shown in fig. 5. It is the device fixed at the end of a robotic arm which is designed to work with the environment. The correct nature of this device relies on the robot's application. The end effector is the final link (or end) of the robot [9]. End effectors may consist of a gripper or a tool. A worm drive is a gear arrangement in which a worm wheel meshes with a worm gear [10].

Typically the gripping mechanism is achieved by the grippers or mechanical fingers. Many a times two-finger grippers are employed in industrial robots as they are constructed for specific tasks and can thus be less complex [11]. The shape of the gripping surface of the fingers depends on the shape of the objects that are to be manipulated. For instance, if a robot has to pick up a round object, the gripper surface could be a concave impression of it which can make an efficient gripping, or for a square shaped object, a plane would be sufficient [12].

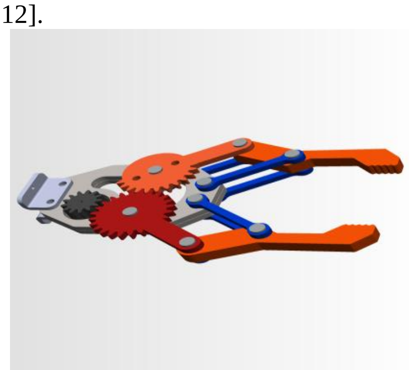

Fig. 5. End Effector with Worm Gear Arrangement

The end effector in assembly line robot would generally be a welding head or a paint spray gun. A scalpel can be the end effector in the case of surgical robots. Some other end effectors are machine tools like a drill or milling cutter [13,14].

III. TECHNICAL DESCRIPTION OF THE Z-ROBOT

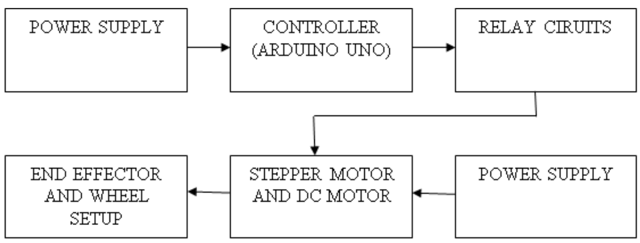

Fig. 6. Block diagram

The process flow used for automating is shown in fig. 6. Arduino controller is used for this process automation. The Arduino UNO controller is actuated by providing 5V DC power supply. Arduino code for this robot automation is developed in Arduino IDE software. The developed code is dumped in Arduino controller. Output for DC motor rotation is taken from the digital pins of the controller. DC motors are actuated by relay circuits.

Out of 4 stepper motors, 2 are used for arm setup, 2 as end effectors and 2 DC motors for wheeling. Both the end effectors have 2 degrees of freedom. These end effectors are connected with two arm setup. These arm setups are placed on the chase with rotating wheels. Each robotic movement is controlled by Arduino controller. Different movements like upward, downward, forward and reverse etc., are controlled.

IV. CIRCUIT CONNECTION OF PROPOSED METHOD

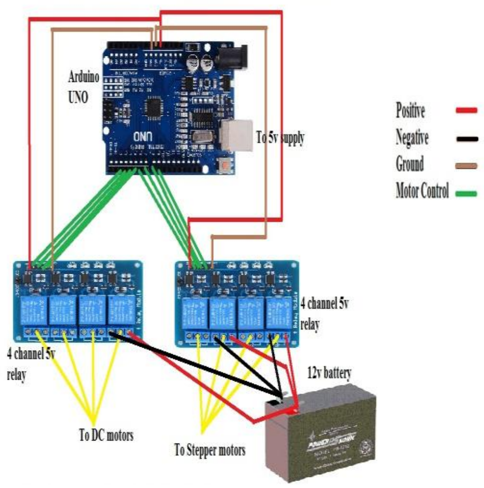

Fig. 7. Circuit Connection of Proposed Method

Circuit connection of the process is shown in the fig. 7. A 5V supply is given to Arduino controller. Program for the motor operations is dumped in the controller by using Arduino IDE software. Outputs from digital pins are given to stepper motors and DC motors via 5V 4 channel relay. Output voltage from the controller is found to be 5V. This 5V is not adequate to operate the motors. Hence an external supply of 12V is given to motors through relay module to actuate the motors.

A. Design Calculations

Table I shows the specification of battery used in the robot as a source. Table II and III show the specifications of DC motor and Stepper motor respectively.

Table I Battery Specification

Supply Voltage	6V
Battery Capacity	4.5 AH
Dimension	70(l)*46(w)*100(h) mm
Battery Charging Time	8-10 hours
Cycle Usage	7.20 V~7.50 V
Standby Usage	6.75 V~6.90 V
Initial current	1.35 A

Table II DC Motor Specification

Speed	30 rpm
Dc Supply	4 V to 12 V
No Load Current	60 mA
Loaded Current	300 mA
Stall Torque	0.202 Nm
Stall Current	0.163 A

Table III Stepper Motor Specification

Supply Voltage	9 V
Step Angle	1.8°
Speed	100 rpm
Supply Current	0.5 A (DC)
Solder Type	Terminal
Inductance Per Phase	23 mH

A.1 Design Calculation of DC Motor

i) Electrical power consumed by the motor

$$\mathbf{Pin = I * V} \quad (1)$$

Where,

Pin = Input Power (Watts)
I = Current (Ampere)
V = Voltage (Volts)

Pin = 3.6 W (for load)
Pin = 0.72 W (for no load)

ii) Mechanical power output from the motor

$$\mathbf{Pout = T * \omega} \quad (2)$$

Where,

Pout = Output Power (Watts)
T = Torque (Newton meter)
ω = Angular Speed (radian/second)

Here, **Torque = 9.5488 * power (W) / speed (rpm)** (3)

Torque = 1.14 Nm (for load)
Torque = 0.22 Nm (for no load)

$$\mathbf{Angular\ Speed = speed\ (rpm) * 2\pi / 60} \quad (4)$$

$\omega = 30 * 2\pi / 60 = 3.14$ rad/s

Therefore, Pout = 3.6 W (for load)

iii) Force calculation for DC motor

Diameter of wheel = 10.5 cm
Radius of wheel = 5.25 cm

Force = Stall Torque/ Radius of wheel (5)
= 20.5 kg cm/ 5.25 cm
= 4 kg

So, the motor can lift up to 4 kg.

A.2 Design Calculation of Stepper Motor

Holding torque = 0.196 Nm
Detent torque = 0.021 Nm
Full revolution = 200 Steps

i) Speed Calculation

$$\mathbf{Maximum\ Speed = V / 2 * L * I_{max} * Steps\ per\ revolution} \quad (6)$$

Where,

L = Stepper Motor Inductance (milli Henry)
I_{max} = Maximum Current (Ampere)

Maximum Speed = 2.6 revolutions / Sec
ii) Maximum Time /Step = 1.92 ms
iii) Maximum Power = 6 W
iv) Force for stepper motor
= 1.9 kg cm

Retrieval Number: K22910981119/2019©BEIESP
DOI: 10.35940/ijitee.K2291.119119
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

So, the motor can lift 1.9 kg on an arm of 1cm length.

A.3 Current Consumed by Stepper and DC Motors

(i) Current consumption of one Stepper motor = 0.5 A
Therefore, for 4 Stepper motors = 0.5 * 4 = 2 A
(ii) Current consumption of one DC motor = 0.3 A
Therefore, for 2 DC motors = 0.3 * 2 = 0.6 A
(iii) Total current consumed by all motors = 2.6 A
If servo motors are used for arm movements, they require 5V, 2A source for motor rotation. And even these servo motors could not lift light weighted objects because torque of servo motors is low for low speed; whereas torque of stepper motor is high for low speed. Hence stepper motors are used for arm movement and end effectors to lift the object. Total current required by these servo motors and DC motors is 2.6A. Voltage required by the stepper motor is 9V and DC motor is 4-12V. Hence the source is chosen as 12V,5Ah.

V. RESULTS AND DISCUSSION

A. Results

The designed robot arm picks up an object and places it on the other side based on the user's command. The fig. 8 shows the total setup of Z-Robot. The fig. 9 shows the opening of end effector. The fig. 10 shows the robot holding an object. The fig. 11 shows the front end of the robot, which has the user instruction window.

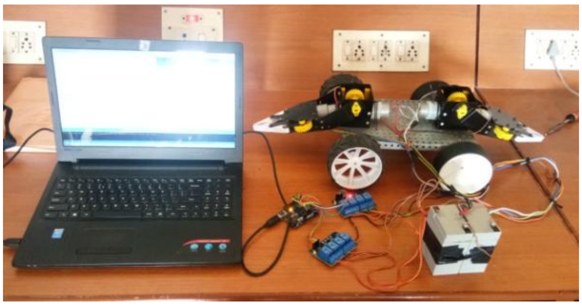

Fig. 8. Hardware model of Z-Robot

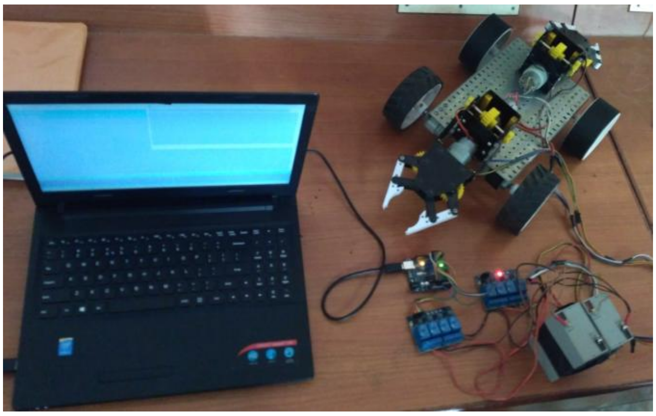

Fig. 9. Opening of End-Effector

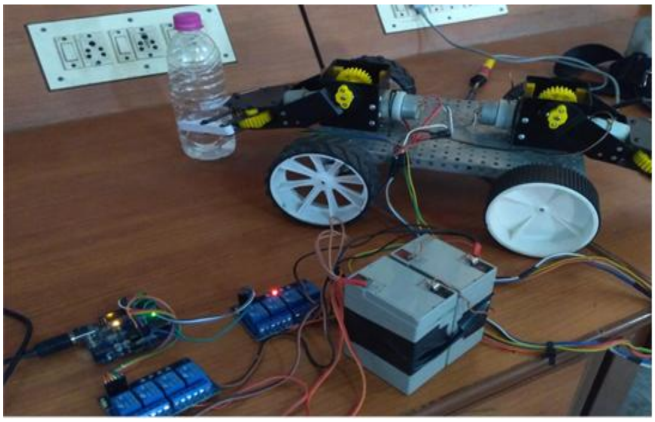

Fig. 10. End-Effector Holding the Object

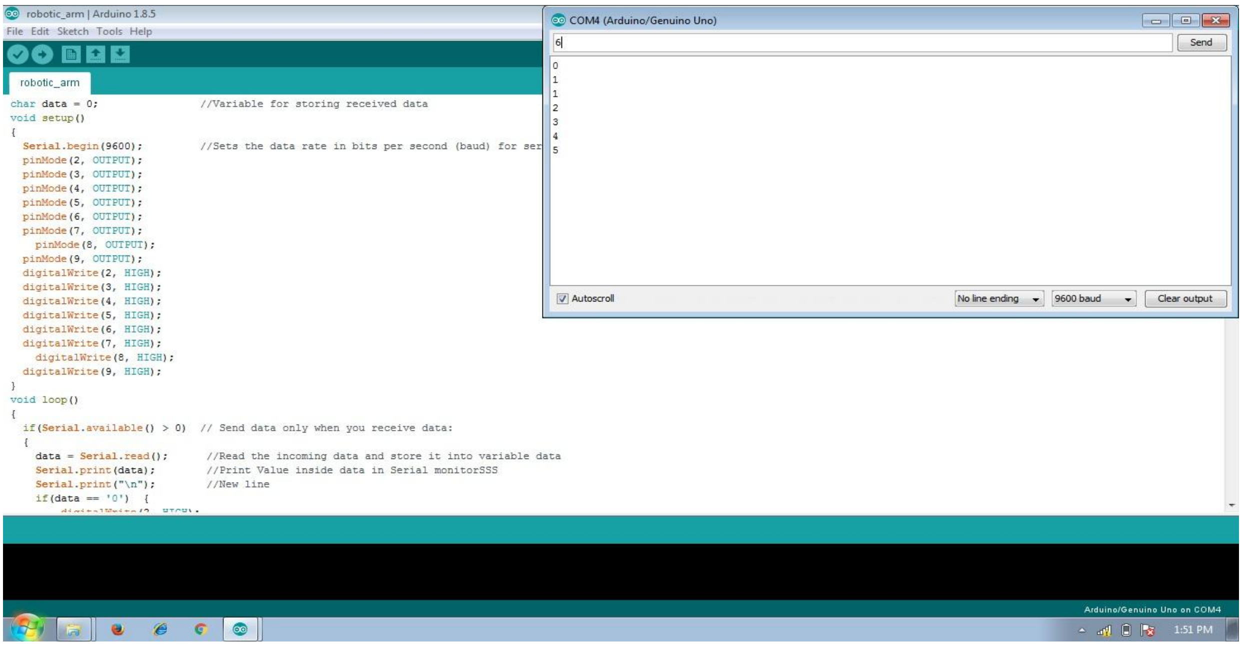

Fig. 11. User instruction window

B. Input Commands for the Robot

Table IV Direction of Motors

User Command	Stepper motor 1	Stepper motor 2	Stepper motor 3	Stepper motor 4	DC motor 1	DC motor 2
0	High	High	No rotation	No rotation	No rotation	No rotation
1	No rotation	No rotation	High	High	No rotation	No rotation
2	Low	Low	No rotation	No rotation	No rotation	No rotation
3	No rotation	No rotation	Low	Low	No rotation	No rotation
4	No rotation	No rotation	No rotation	No rotation	Forward	Forward
5	No rotation	No rotation	No rotation	No rotation	Reverse	Reverse
6	No rotation	No rotation	No rotation	No rotation	Reverse	Forward
7	No rotation	No rotation	No rotation	No rotation	Forward	Reverse

The above table IV represents the working direction of motors. The user can give the commands from 1 to 8 as input. For example if the user gives the input as 0, stepper motors 1 and 2 attain high position and the arm setup moves up. If the user gives the command as 1, stepper motors 1 and 2 attain low position and the arm setup moves down. If the user gives the input as 2, stepper motors 3 and 4 attain high position and the end effector closes. If the user gives the command as 3, stepper motors 3 and 4 attain low position and the end effector opens.

Two DC motors are used for wheel setup. One motor is fixed to the back side of right wheel and the other to left wheel. If the user gives the command as 7, both the motors rotate in forward direction and the robot moves left side to perform its operation. If the user gives the input as 6, both the motors rotate in reverse direction and the robot moves right side. If the user gives the command as 4, one motor rotates in forward direction and the other rotates in reverse direction to move the robot front. And if the user gives the command as 5, the motors rotates vice versa to move the robot back.

Table V Time Taken for Robot Movement

S.NO	ROBOT MOVEMENT	TIME TAKEN(SEC)
0	Arm Up	2
1	Arm Down	2
2	End-effetcor Close	1
3	End-effector Open	1
4	Forward	1.5
5	Reverse	1.5
6	Right	1.5
7	Left	1.5

Table V shows the time taken by the robot to perform its pick and place operation. Time taken for each movement of the robot depends on the time delay of the operation fed in the Arduino controller. This delay can be changed by the programmer.

V1. CONCLUSION AND FUTURE SCOPE

A. Conclusion

Thus the position of robot arm is controlled using Arduino controller until pressing reset or power cutoff. After pressing reset the robot is ready for new work. By this way, the man power in the industry can be reduced and production can be increased. The dual-arm design has given solutions to production environments demanding a higher level of agility. The capability to make the dual-arms to operate either collaboratively or independently enables them to be competent in executing an extremely broader range of assembly, picking, and tending applications.

Today we come across most robots which help for people in industries, factories, warehouses, and laboratories. Robots are helpful in many ways. For example, they boost the economy since businesses need to be proficient to sustain with the industry competition. As a result, employing robots helps business owners to be competitive, since robots can do jobs superior and sooner than humans can, e.g. a robot can build, assemble a car easily. However robots cannot execute every job; today the role of the robots includes assisting research and industry. To conclude, as the technology grows, there will be new methods to employ robots which will fetch new hopes and new potentials.

B. Future Scope

This idea can be extended into a bigger industrial robot arm, which can handle large number of processes in industries. Robotic arms further lessen work-related injuries and accidents. Workers are kept clear of hazardous environments, toxic fumes and tedious, sometimes injury-inducing work by employing the robots with necessary safety aspects. All these benefits continue to grow as robots persist to get better and improve over time.

REFERENCES

1. "Bill" Griffith P.Taylor, 'The Robot Gargantua', Meccano Magazine, March 1938.
2. Francis Bourbonnais, Pascal Bigras, and Ilian A. Bonev, 'Minimum-Time Trajectory Planning and Control of a Pick-and-Place Five-Bar Parallel Robot', IEEE/ASME Transactions On Mechatronics, 2014.
3. https://www.elprous.com/stepper-motor-types-advantages-applications/
4. https://circuitdigest.com/article/stepper-motor-basics
5. https://www.electronicshub.org/stepper-motors/%3famp

6. Leo Louis, "Working principle of arduino and using it as a tool for study and research", International Journal of Control, Automation, Communication and Systems (IJCACS), Vol.1, No.2, April 2016
7. https://whatis.techtarget.com/arduino-uno-basics/
8. https://www.techopedia.com/arduino-pin-configurations
9. Kathy ceceri, 'Making Simple robots', Maker Media, Incorporated, 2016.
10. MC Zhou, 'Modeling and deadlock avoidance of automated manufacturing systems with multiple automated guided vehicles', IEEE Transactions on Systems, 2010.
11. Renato M.E. Sabbatini. 'Sabbatini, RME: An Imitation of Life: The First Robots', Journal of Mechanical Design, 2008.
12. Richard C Dorf, 'Robotics And Automated Manufacturing', Reston Publishing Co, 2017.
13. Sfakiotakis; et al. (1999). 'Review of Fish Swimming Modes for Aquatic Locomotion', IEEE Journal of Oceanic Engineering, 2007.
14. Tian Huang, Zhanxian Li, Meng Li, 'Conceptual Design and Dimensional Synthesis of a Novel 2-DOF Translational Parallel Robot for Pick-and-Place Operations', Journal of Mechanical Design, 2004.

AUTHORS PROFILE

Dr. J. Indra received her Bachelor's Degree in Electrical and Electronics Engineering from the Bharathiyar University, Master's Degree in VLSI Design from Anna University, Chennai and PhD in Information and Communication Engineering from Anna University, Chennai. She is University IV rank holder in her UG and Gold Medallist in PG. She is holding 16 years of experience and currently working as Associate Professor in the Department of Electronics and Instrumentation Engineering at Kongu Engineering College, one of the premier institutions in Tamilnadu. She has published around 20 papers in various international and national journals. She is a Life Member of International association of Engineers**.** Her research interests include VLSI Design, Energy Efficient Embedded Systems, Speech Signal Processing and IoT.

Dr. R. Kiruba Shankar received his Bachelor's Degree in Instrumentation Engineering from the Bharathidasan University, Master's Degree in Control & Instrumentation Engineering from Anna University, Chennai and PhD in Electrical Engineering from Anna University, Chennai. He is Certified LabVIEW Associate Developer (CLAD) issued by National Instruments, Texas, U.S. He is holding 15+ year's experience, including more than 12 years of academic experience, presently he is working as Associate Professor in the Department of Mechatronics Engineering at Kongu Engineering College, one of the premier institutions in Tamilnadu. His research areas of interest include Control system & Instrumentation, Internet-Based Control System, Industrial Automation, Virtual Instrumentation, Process Control and Soft Computing.

N.Ilakkiya is doing her third year B.E. Electronics and Instrumentation Engineering at Kongu Engineering College, Perundurai, Erode. She is interested in doing real time projects

S.Indujha is doing her third year B.E. Electronics and Instrumentation Engineering at Kongu Engineering College, Perundurai, Erode. She is interested in implementing real time projects

S.Guhan is doing his third year B.E. Electronics and Instrumentation Engineering at Kongu Engineering College, Perundurai, Erode. He is interested in designing and implementing real time projects