Design and Fabrication of Pick and Place Robot using Microcontroller

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Abstract: ***Robotic arm has become popular in the world of robotics. The essential part of the robotic arm is a programmable microcontroller-based brick capable of driving basically 3 stepper motors design to form an anthropomorphic structure. In this anticipate an automated arm with four degrees of opportunity is composed and can pick the items with a particular weight and place them in a sought area. To encourage the lifting of the items, Servomotors are utilized. This abstract explains the method of interfacing the robotic arm stepper motors with the programmed PIC16F877A based microcontroller which are used to control the robot operations. A sample robot which can grab and release small objects is built for demonstrating the method explained. In this project, the main application is control of multiple operations and movement of conveyer using time-based Microcontroller. The initial phase of the project focuses on passing the inputs to the microcontroller so as to identify the number of different workstations available in the industry which are specified by the user. Automated pick and place a framework comprises of a preparing station, testing station, and sorting station.***

Keywords: Robotic arm, Gripper, Gear motor, Actuator, Controller, End effector

1. Introduction

The field of robotics has its origins in science fictions. The word robot comes from the Czech word "robota" means forced labor in 1920. It took another 40 years before the modern technology of industrial robotics began. Today, robots are highly automated mechanical manipulators controlled by computers. A robot may appear like a human being or an animal or a simple electro-mechanical device. A robot may act under the direct control of a human (e. g. the robotic arm of the space shuttle) or autonomously under the control of a programmed computer. Robots may be used to perform tasks that are too dangerous or difficult for humans to implement directly (e. g. nuclear waste cleanup) or may be used to automate repetitive tasks that can be performed more cheaply by a robot than by the employment of a human (e. g. automobile production) or may be used to automate mindless repetitive tasks that should be performed with more precision by a robot than by a human (material handling, material transfer applications, machine loading and unloading, processing operations, assembly and inspection). [1]

The last two decades have witnessed a significant advance in the field of robots application. Many more applications are expected to appear in space exploration, battlefield and in various actives of daily life in the coming years. A robot is a mechanical device that performs automated tasks and movements, according to either pre-defined program or a set of general guidelines and direct human supervision. These tasks either replace or enhance human work, such as in manufacturing, contraction or manipulation of heavy or hazardous material. Robot is an integral part in automating the flexible manufacturing system that one greatly in demand these days. Robots are now more than a machine, as robots have become the solution of the future as cost labour wages and customers demand. Even though the cost of acquiring robotic system is quite expensive but as today's rapid development and a very high demand in quality with IS0 standards, human are no longer capable of such demands. Research and development of future robots is moving at a very rapid pace due to the constantly improving and upgrading of the quality standards of products. [2].

Robotic manipulators resembling the human arm is known as robotic arms. They are constructed by a structure consisting of structurally robust links coupled by either rotational joints or translating joints. A robotic arm is thus a type of mechanically coupled or joined arm, run by programmable commands, with similar functions to a human arm. It may be the sum total of the mechanism links or may be part of a more complex sized robot. A typical robotic arm has the following components: • Links and joints • Actuators • Controller • End-effector A link is considered as a rigid body that defines the relationship between two corresponding joint axes of a manipulator. Manipulators consist of rigid links, which are connected by joints that allow relative motion of corresponding links. The links move to position with the end-effector. Actuators perform the same role the muscles perform in the human arm – they convert stored energy into movement energy. Actuators are used force to move a robot's manipulator joints. The three common types of actuators currently using in contemporary robots are pneumatic, hydraulic, and electrical actuators. [3]

The robots play important roles in our lives and are able to perform the tasks which cannot be done by humans in terms of speed, accuracy and difficulty. Robots can be employed to imitate human behaviours and then apply these behaviours to the skills that leads the robot to achieve a certain task [1]. They do not get tired or face the commands emotionally, and since they are designed by humans. They can be programmed and expected to obey and perform some specific tasks. In some cases the use of a robotic hand becomes remarkable. Robotic is applied in different forms and fields to simulate human behaviour and motions [4].

The first usage of the word 'robot' was in a 1921 Czech science fiction play – 'Rossum's Universal Robots' – by Karel Capek. The robots were artificial people or androids and the word was derived from the word 'Robata', a Czech word for slave. A question of perpetual interest is to define a robot. Since the beginning of the study of robotics, there has been some controversy in the definition of a robot. So long as the evolution of robotics continues, the definition of the robot will change from time to time, depending on the technological advances in its sensory capability and level of intelligence. However, the most widely accepted definition of a robot was given by the Robotic Institute of America (RIA) in 1979.

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Electric motor-driven actuators perform smoother movements, can be controlled very accurately, and are very reliable. However, these actuators cannot deliver as much power as hydraulic actuators of comparable mass. Nevertheless, for modest power actuator functions, electrical actuators are often preferred. The various types of electric motors used as actuators for robotic applications are direct current (DC) motors, stepper motors and servo motors. The controller is the main part that processes information and carries out instructions in a robot. It is the robot's 'brain' and controls the robot's movements. It is usually a computer of some type which is used to keep information about the robot and the working process and execute programs which operate the robot. It contains programs, data algorithms, logic analysis and various other processing activities which enable the robot to perform its intended function.

End-effector is a device at the end of a robotic arm, designed to interact with the open world. The exact nature of performance of this device depends on the application of the robot. Typical functions of the end-effector consist grasping, pushing and pulling, twisting, using tools, performing insertions, welding and various types of assembly activities. Thus, the major types of robot end-effectors are:

- **Grippers:** Grippers are the most commonly used type of end-effectors. They can use different gripping methods (such as vacuum or use of fingers).
- **Material removal tools**: These include cutting, drilling and deburring tools installed as robot tools.
- **Welding torches**: Welding is a widely using operation in robotic application. Welding torches have become very efficient end-effectors that can be controlled in a sophisticated way for optimized welding.
- **Tool changers**: Tool changers are used when many different end effectors need to be used in sequence by one robot. They are used to standardize the interface between the robot flange and the base of the tool. They can be manual or automatic

1.1 Material Selection

The most suitable material to fabricate the structure of the arm has to be light and strong. Otherwise, the servo motor will not be able to pull up the arm and to perform the desired turning degree. Among the materials that can be considered to fabricate the structure are aluminum, Perspex, plastic polymer and carbon fiber. In choosing the fabrication materials, the aspect of availability of the materials, the overall cost and the flexibility to be shaped, should also be taken into consideration. Thus among the four materials considered, the aluminium is the most ideal material to be chosen as fabrication material.

1.2 Design Consideration

The following were put into consideration in the design process,

1) Electrical actuators DC servo are chosen instead of hydraulic and pneumatic actuators because of the little power requirement and its light weight which is suitable for this design.
2) Materials used for the fabrication were locally sourced from available materials.
3) The materials which will be used for the design will be light in weight so as to reduce the weight concentration on the base and the shoulder.
4) A continuous path controller was chosen (PIC microcontroller was used).
5) The torque is fully balanced by the inertia of the electric motors.

1.3 Robot Arm Details and Summary

The robotic arm will be controlled via the designed controller and it will be able to grab, pick up and move objects according to their weights and shape. The manipulator design is mostly expected to pick up cubes and the geometric shapes like a box. Depending on the numbers of joints, DOF differs, but generally robotic arms operate using 4 or 5 servo motors. The servo motors are popular for their desirable characteristics for robotic application [6].

1.4 Problem Statement and Proposed Solution

This study intends to investigate the design, implementation and control of a 5 DOF articulated robotic arm using servo motors and PIC 16F877A microcontroller. The advantage of this microcontroller its low cost and in-circuit programmability [5]. A pulse could have a different effect on servos with different specifications. Therefore, most of the time it is crucial to be able to give the exact PWM pulse in order to rotate a servo to a specific rotation. The main advantage of controlling the servo motors with PWM signals is that they can be programmed to have an initial position and to rotate with an exact degree with respect to the requirements [6].

2. Objectives

The primary objective is to make the Robotic arm, which comprises of three stepper motors, to interface with the PIC-based micro-controller. It provides more interfaces to the outside world and has larger Memory to store many programs.

1) To develop automated robotic handling system in manufacturing plant for multi-tasking application.
2) To synchronize multi-tasking functions using microcontroller sequencing by distributed time.
3) To validate the functioning of automated robotic system (qualitative and quantitative analysis).
4) To monitor and control the overall functioning of the manufacturing plant by connecting it with the LCD Screen or a computer by attaching a camera to the robotic arm.

3. Project Methodology

This project is designed with,

Hardware Requirements:

- Microcontroller (PIC16F877A)
- Oscillator Circuit
- Relay driver
- Relay
- Power Supply
- Battery (12v)
- DC Geared motor
- Wiper motor

3.1 PIC 16F877A Microcontroller

PIC 16F877A microcontroller has 40 pins and is a popular microcontroller capable of doing complex tasks. This microcontroller has 8192 × 14 flash program memory which consists of 368 bytes of RAM and 256 bytes of non-volatile EEPROM memory.33 pins are dedicated for input/output pins and 8 multiplexed analog/digital converters with 10 bits resolution. This microcontroller also has specifications such as PWM (Pulse Width Modulation) generator, 3 timers, analog capture and comparator circuit, universal synchronous receiver transmitter (USART), internal and external interrupt capabilities. Figure 21 shows the pin configuration of the PIC 16F877A microcontroller and the pins which are used for PWM generation are marked [7].

3.2 Block Diagram

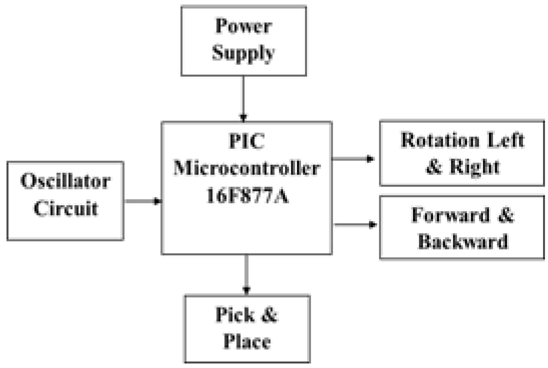

Figure 3.2.1: Block Diagram of the model

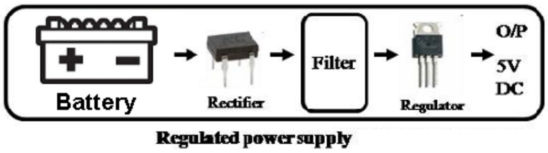

Figure 3.2.2: Regulated Power Supply

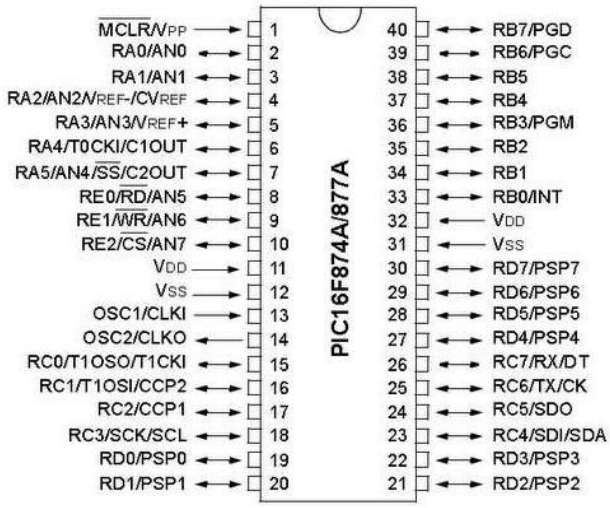

Figure 3.2.3: Block Diagram of PIC16F877A Microcontroller

3.3 Power Supply (Lead Acid Battery)

A power supply is an electronic device that supplies electric energy to an electrical load. The primary function of a power supply is to convert one form of electrical energy to another.

3.4 D C Geared Motor

A geared motor is a specific type of electrical motor that is designed to produce high torque while maintain the low speed, motor output. A gear motor can be either an AC or a DC electric motor. In this project we are using DC geared motor which has the output about10-30 revolutions per minute. Gear motors are primarily used to reduce speed in a series of gears, which in turn creates more torque. Gear motors are commonly used in commercial applications where a piece of equipment needs to be able to exert a high amount of force in order to move very heavy object. Examples of these types of equipment would include a crane or lift jack, and in smaller applications like Pick and Place Robots also.

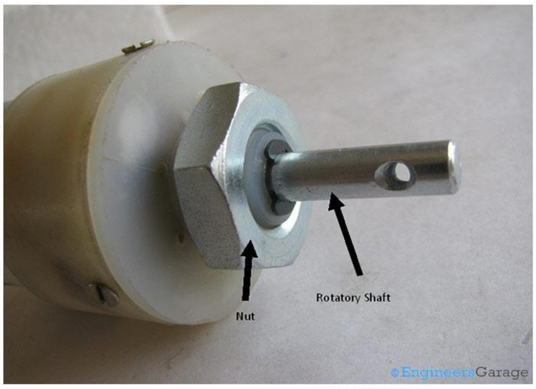

Figure 3.4.1: DC Geared Motor

Figure 3.4.2: Wiper Motor

Figure 3.4.3: Servo Motor or Mini DC Motor

4. Calculations

1. Servo Motor of 12V with Power 3W

P=2*3.142*N*T/60 where N=60rpm
3=2*3.142*60*T/60
T= 3*60/2*3.142*60
T= 0.47Nm

Torque= Force * Perpendicular Distance
Force= Toque / Distance where Distance= 0.08m
Force= 0.47 / 0.08
Force= 5.878 N

Force= Mass * Acceleration Due to Gravity
Mass= Force / Acceleration Due to Gravity
Mass= 5.878 / 9.81
Mass= 0.58Kg (Robot can lift)

2. Torque of DC geared motor of 12V with Power 5W and N=20rpm

Power= 2*3.142*N*T / 60
Torque= 5*60 / 2*3.142*20
` Torque= 2.38Nm

3. Wheel Motor with a Torque of 5Nm

Torque= Force * Perpendicular Distance
Force= 5 / 0.07
Force= 71.42 N
Mass= Force / Acceleration Due to Gravity
Mass= 71.42 / 9.81
Mass= 7.28 Kg

4.1 Results

This work is able to successfully accomplish the defined functionality. A sample robot which can rotate, magnetize an object, lower and raise its arm, by being controlled by the 8051 microcontroller is built successfully. The 8051-development board is soldered and it used the required procedure for the correct operation of the controller. The 8051 development board has been interfaced to the stepper motors such that the anthropomorphic like structure can be controlled from the buttons at the base of the structure (*robotic arm*).

There are four buttons being controlled by the control unit at the base of the arm:

1) **ON/OFF:** the ON button puts on the system while the OFF button puts off the system
2) **START/STOP:** the START button starts the movement of the whole arm from its reset point, while the STOP button takes the arm back to its reset button after completion of its movement.
3) **RIGHT-LEFT/LEFT-RIGHT:** when this button is switched to the RIGHT-LEFT part it causes movement from right to left, while the LEFT-RIGHT part causes movement from left to right.
4) **4.180/90**: when the button is on 180, it causes a rotation of 180 degree of the base stepper motor, but when put on 90 degrees, it causes rotation of 90 degrees.

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5. Advantages, Disadvantages and Applications

5.1 Advantages

1) **Accuracy and Pick and Place Robots:** Robots are outfitted with wide reaches and slim arms, steady repeatability and precise tooling-all of which allows them to be extremely accurate. This high precision capability makes them a good match for pick and place applications.
2) **Flexible Pick and Place:** One of the main advantages of robotics is flexibility. Pick and place robots are easily programmable. They are able to accommodate multiple changes in product shape and type. In addition, robots provide a high level of movement flexibility.
3) **Increase Consistency with Pick and Place:** Pick and place robot systems have the ability to improve product quality and cycle time. Robotic movements are regulated, so the results are always the same. Quality is improved because of this regularity. Furthermore, this consistency allows the processes to take place.
4) **Robots are Space-Efficient:** Because they are designed with compact bases, pick and place robots are ideal if you are looking to conserve floor space. Robots can be programmed to move within strict work envelope limits-leading to even better use of space.
5) **Robots Maximize Safety:** Pick and place applications can be physically demanding. They are labor-intensive, repetitive, and monotonous. Depending on the weight and size of a part, moving it from one place to another can be very demanding work. Pick and place robots are unaffected by the stresses of the application. They are able to work without taking breaks or making mistakes.
6) **Save with Pick and Place Robots:** Incorporating pick and place robots can effectively cut your costs. Robotic precision and reliability allow for less wasted material and more efficient use of time. Plus, the initial investment in robots is quickly recouped-making pick and place robots an extremely cost-effective solution.

5.2 Disadvantages

1) **Expense:** The initial investment to integrated automated robotics into your business is significant, especially when business owners are limiting their purchases to new robotic equipment. The cost of robotic automation should be calculated in light of a business' greater financial budget. Regular maintenance needs can have a financial toll as well.
2) **ROI:** Incorporating industrial robots does not guarantee results. Without planning, companies can have difficulty achieving their goals.
3) **Expertise:** Employees will require training program and interact with the new robotic equipment. This normally takes time and financial output.
4) **Safety:** Robots may protect workers from some hazards, but in the meantime, their very presence can create other safety problems. These new dangers must be taken into consideration.

5.3 Applications

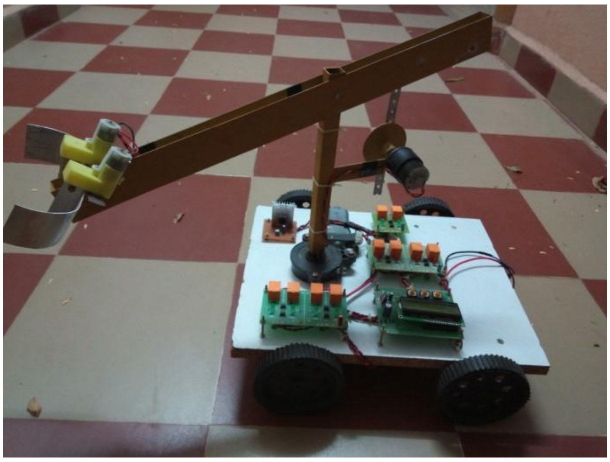
1) Material Handling
2) Industrial Robotic Application
3) Welding
4) Spraying
5) Trimming and Sealing
6) Coal Mining
7) Military Operations

6. Conclusion

In this project we have interfaced the robot with different kinds of I/O devices and our method allows for storing more programs to enhance more functionality. From our work, we deduced that in comparison to humans, robots can be much stronger and are therefore able to lift heavier weights and exert larger forces. They can be very precise in their movements, reduce labor costs, improve working conditions, reduce material wastage and improve product quality. This is why they're very important in industries because the overall objective of industrial engineering is productivity.

In this project, the procedure of building an articulated arm robot using a microcontroller (PIC16F877A) and servo motors with the help of PWM has been discussed. The building procedure consists of building the kinematic structure of robot, hardware design and implementation, software design and implementation and microcontroller programming.

It is important to recall that each servo motor has a different pulse width range where a pulse can have different effects on each servo, therefore it is important to first simulate the system and then implement it accordingly. It is also essential to consider the built-in oscillator of the microcontroller which is usually 1MHz. Different values of the oscillator can cause the system to not operate properly.



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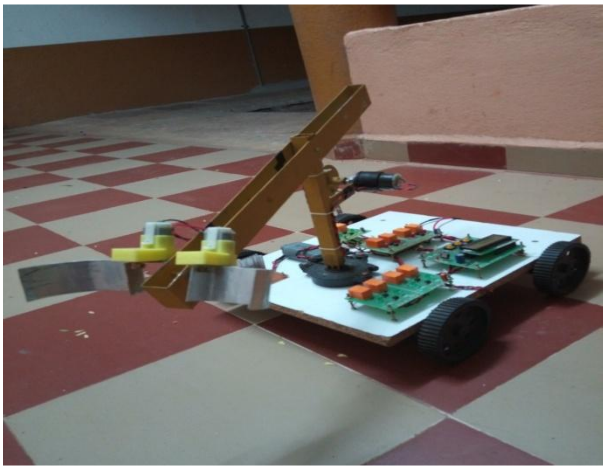

Figure 6.1 and 6.2: Final ready Working Model Picture

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