Economical and Effective Method for Design and Fabrication of Pick and Place Robot

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Abstract: ***In modern world, Information and Technology has overtaken traditional practices for various objectives in the field of Engineering and research. One of the significant inventions of this era is a robot. There are many different reasons for using a robot but the central reason for most applications is to eliminate a human operator and reduce cost. Evolution of robots has led to a work specific robot called as a pick and place robot. Basically, a pick and place robot is an electrically or mechanically driven mechanism attached to and controlled by a gripper for loading and removing a part. This project proposes an economical and effective method for design and fabrication of a pick and place robot. The design process begins by specifying top level of the manipulator's structure to all subsequent components by using acrylic sheets. By considering the mechanical arm's performance objectives, the design starts with modelling the integration of all individual links constituting the manipulator. During the design process, modifications are made based on integrated information of kinematics, dynamics and structural analysis of the desired robot configuration as a whole. This involves components such as base box, mechanical arms, servo motors and arduino microcontroller. The sole purpose of using acrylic sheets is that it is light in weight and is stable. Grippers are used to pick and place the components and the movement is carried with the help of servo motors. It has got built in pressure sensor which prevents dropping and breaking. The advantage of this robotic mechanism over existing models is that it is economical, light weight and portable, also has repeatability within tolerance limits.***

Keywords*:* Economical, Acrylic material, Arduino programming, servo motors, Portable etc

1. Introduction

Robot is an automatically controlled material handling unit that is widely used in the manufacturing industry. Robots are generally used for high volume production. An industrial robot is a reprogrammable, multifunctional, manipulator, designed to move materials, parts, tools or special devices through a variable program motions for the performance of variety of tasks. All robots contain some level of computer programming code. The program refers to the information that how a robot decides when or how to do something. A robot with remote control programming has a pre-existing set of commands that it will only perform if and when it receives a signal from a control source. 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 is usually with ISO (International Standard Organization) 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. Robot and automation is employed in order to replace human to perform those tasks that are routine. In a world of advanced technology today automation greatly increases production capability, improves product quality and lowers reduction cost. There are many different reasons for using a robot but the central reason for most applications is to eliminate a human operator and reduce cost. Evolution of robots has led to a work specific robot called as a pick and place robot. The pick and place robot is a human controlled mechanical system that detects the object, picks that object from source location and places at desired location. For detection of object, human detect presence of object and machine accordingly. These pick and place robots are more accurate and do not fatigue while doing back- breaking or hard to maneuver movements that may be difficult for human.[1]

2. Design of Pick and Place Robot

The mechanical components used in the design of pick and place robot are as follows. Electrical actuators namely servo motors are chosen instead of hydraulic and pneumatic actuators because of the little power requirement and its light weight which is suitable for this design. 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. Acrylic sheets are used for the links because of their light weight and stability and to reduce the weight of the arm. The power supply source will be from a USB powered source with an external power source (battery) if required. A continuous path controller (Arduino Uno microcontroller) is used. The torque is fully balanced by the inertia of the electric motors and the speed is greatly reduced. Materials used for the fabrication were locally sourced from available materials [2].

3. System Description

The robotic arm has five degrees of freedom. The arrangement of these links depends on the design finalized. The arm has a base that is resting on the four hexagonal head bolts. The arm terminates with a gripper; it has five degrees of freedom. For the purpose of analysis, the robotic arm will made of joints, which will be named as gripper, wrist, elbow, shoulder, and base. The preliminary sketch from which the detailed design was made is based on the sketch.

a) End Effector
This is the gripper, whose operation is to grip and outgrip the objects to be lifted or moved. The gripper is connected to the horizontal rotating servo motor.
b) Wrist
This is the joint that links to the end effectors. The wrist has one degree of freedom, which is actuated by a servo motor. It can rotate to about 180° about the horizontal axis.
c) Elbow
This is the joint between shoulder and wrist and it has one degree of freedom actuated by a servo motor. It can rotate to about 180° (by design).
d) Shoulder
This is the joint between elbow and the base and has one degree of freedom which is actuated by a servo motor. It can also rotate to about 180°.
e) Base
This is the joint between the robotic arm and the hexagonal head bolts; it has one degree of freedom which is actuated by a servo motor. The servo motor is similar to that used in the shoulder. The base rotates to about 180°. The base is the platform on which the arm stands and it carries the weight of the arm which in turns determine maximum load the robotic are can lift. The circuit board wiring and other attachments are fixed to the base.

4. Design Analysis of Robotic Manipulator

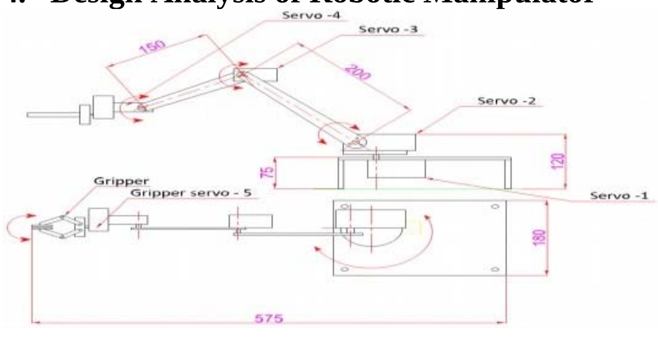

Figure 1: Design of the pick and place robot

4.1 Robot arm torque

Neglecting the weight of motors only considering the weight of arms

Considering the arm as a single link.
Torque imposed by the arm itself:
$= (mg * L) + (W * L/2)$
$= L*(mg + W/2)$
$= 0.30*(0.2*9.81 + (0.18*9.81)/2)$
$= 0.85Nm$

4.2 Torque at each joint

$T_1 = (mg * L_2) + (W_3 * L_2/2)$
$= (0.2*9.81*0.15) + (0.09*9.81*0.15/2)$
$= 0.36Nm$

$T_2 = (mg*(L_2+L_1)+(W_3*(L_1+L_2/2))+(Wm_3*L_1)+(W_2*L/2)$
$= (0.2*9.81*0.30)+(0.09*9.81*0.225)+(0.056*9.81*0.15) + (0.09*9.81*0.075)$
$= 0.935Nm$

4.3 Stress acting

Stress on arm 1 = F/A
= 0.2+0.09 * (9.81)/7500
= 3.8x10-4MPa
Stress on arm 2 = F/A
= 0.2+0.09+0.09 * (9.81)/7500
= 4.97x10-4MPa
Acrylic Material = 69MPa

4.4 Moments sustained at each joint

In this aspect numerous calculations was done in order to attain the required servo mechanism that will meet the specification on this work.

Moment = force * perpendicular distance

Assuming that the weight of the material is negligible since it is light compare to the servo specification, Weight of servos is as follows:

W0=W1=W2=W3=0.55N, W4=0.09N

Moment sustained at the shoulder
$M_1 = (0.009 \times 38) + (0.056 \times 30) + (0.056 \times 15)$
$= 0.28Nm$
But actual torque of the shoulder servo = 1.27Nm
Excess torque = Actual servo torque – Calculated torque
Therefore excess available torque at the shoulder = 1.27-0.28 = 0.99Nm

Moment sustained at the elbow
$M_2 = (0.009 \times 23) + (0.056 \times 15) = 0.10Nm$
But actual torque of the Arm servo = 1.27Nm
Excess available torque at the elbow = 1.27-0.10 = 1.17Nm
Moment sustained at wrist
$M_3 = (0.009 \times 8) = 0.00706Nm$
But actual torque at the wrist servo = 1.27Nm
Excess torque =1.27 – 0.00706 = 1.26Nm
From the design analysis made, the maximum load the robotic manipulator can lift successfully is determined by the base servo. The actual load will be less than the calculated value because the weight of the material used in constructing the arm was light and was not taken into consideration.

5. Construction

a) Base
The base is constructed using acrylic sheets of dimensions 225mm x 180mm of thickness 5mm.

b) Arm
The robotic arm consists of two links of 150mm each with a thickness of 5mm made up of acrylic sheets.

c) Servo Motors
Servo refers to an error sensing feedback control which is used to correct the performance of a system. Servo or RC Servo Motors are DC motors equipped with a servo mechanism for precise control of angular position. The RC servo motors usually have a rotation limit from 90° to 180°. But servos do not rotate continually. Their rotation is restricted in between the fixed angles. The Servos are used for precision positioning. They are used in robotic arms and legs, sensor scanners and in RC toys like RC helicopter, airplanes and cars. Servo Motor Parts A servo motor mainly consists of a DC motor, gear system, a position sensor which is mostly a potentiometer, and control electronics. The DC motor is connected with a gear mechanism which provides feedback to a position sensor which is mostly a potentiometer. From the gear box, the output of the motor is delivered via servo spline to the servo arm. The potentiometer changes position corresponding to the current position of the motor. So the change in resistance produces an equivalent change in voltage from the potentiometer. A pulse width modulated signal is fed through the control wire. The pulse width is converted into an equivalent voltage that is compared with that of signal from the potentiometer in an error amplifier[3].

d) Arduino Microcontroller
The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. The Arduino Uno can be powered via the USB connection or with an external power supply. External (non-USB) power can come either from an AC-to-DC adapter or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and VIN pin headers of the POWER connector [4].

6. Servo and Microcontroller Specifications

i) Gripper Servo
Wire length – 18cm
Weight – 13.5 g

At 4.8V
Speed (sec/60°): 0.13
Torque (Kg-cm): 1.2

At 6V
Speed (sec/60°): 0.10
Torque (Kg-cm): 1.4

ii) Wrist Servo
Wire length: 30 cm
Weight: 72 g

At 4.8V
Speed (sec/60°): 0.18
Torque (Kg-cm): 9

At 6V
Speed (sec/60°): 1.6
Torque (Kg-cm): 12

iii) Elbow Servo
Wire length: 30 cm
Weight: 72 g

At 4.8V
Speed (sec/60°): 0.18
Torque (Kg-cm): 9

At 6V
Speed (sec/60°): 1.6
Torque (Kg-cm): 12

iv) Shoulder Servo
Wire length: 30 cm
Weight: 72 g

At 4.8V
Speed (sec/60°): 0.18
Torque (Kg-cm): 9

At 6V
Speed (sec/60°): 1.6
Torque (Kg-cm): 12

v) Base Servo
Wire length: 30 cm
Weight: 72 g

At 4.8V
Speed (sec/60°): 0.18
Torque (Kg-cm): 9

At 6V
Speed (sec/60°): 1.6
Torque (Kg-cm): 12

vi) Microcontroller

Table 1: Microcontroller specifications

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

7. Fabrication

Laser cutting machine is used in the fabrication of the robot arm structure.

a) Laser Cutting of Acrylic Material

Acrylic is the base material used for the fabrication of the model. This material is cut to required dimensions and specifications using a CO2 laser. A layer of plastic vinyl is used to mask the laser cutting operation on the acrylic sheet so that imperfections are not caused on the surface of the material. Arm length of 150mm, width of 50mm and thickness of 6mm is the standard design criteria. Cuts are provided for proper slotting of the Servo Motors, gear fasteners, screws etc. All cuts are made to calculated design requirements.

b) Constructing Servo Controller Circuit

The servo motor has three leads. The colour of the leads varies between servo motors, but the red lead is 5V and GND will either be black or brown. The other lead is the control lead and this is usually orange or yellow. This control lead is connected to digital pin 9. The servo is conveniently terminated in a socket into which we can push jumper wires, to link it to the breadboard and then to the Arduino. In the similar fashion, five servo are connected to the breadboard.

c) Wiring

Colour code is specified and is the general set up for all servo motors.

Black: Negative lead

Red: Positive lead

White: Pulse Width Modulation Signal

Power of 5V is provided to the operation of servo motors using a microcontroller. Equal power is supplied to all the servos by use of a bread board.

d) Assembly

Finally, the above electromechanical components are assembled to obtain the final design of the pick and place robot.

References

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