MICRO-CONTROLLER BASED ROBOT ARM WITH THREE-DIMENSIONAL REACH

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ABSTRACT

Robotic arms are used in lifting heavy objects and carrying out tasks that require extreme concentration and expert accuracy. This study mainly focuses on the accuracy in control mechanism of the arm while gripping and placing of objects. A design has been proposed to replicate an industrial robot arm with a reach in a three dimensional space which could pick and place objects specified. The three dimensional space access mechanisms operate in cylindrical coordinate system. The operating domain is a cylindrical sector of a fixed radius and height and limited rotation. A four jaw angular gripper will be of use to grip the object firmly with a precise stress. The gripping precision could be defined for objects within the specified dimension of the object. The stress on the object can be controlled. The system facilitates autonomous object detection within its limitations. A user interface is incorporated with the system for human input feed on the desired destination within the working frontiers. The targeted destination is specified in terms of height, radius and angle. In addition the orientation of the object can be provisioned along with the destination.

Keywords: Robot arm, Pick and Place, Industrial robotics

1.0 INTRODUCTION

Some tasks of robot arms may relate to simple mechanisms of picking an object and placing it somewhere. An automated pick and place robot arm, which can reach an object in a given domain or range of space, grip it precisely, change its orientation and place it in a given position will ease the functions mentioned earlier. Thus, it could be named as a Robot Arm with a Three Dimensional Reach. Robotic arms are mechanically controlled devices designed to replicate the movements of a human arm. These devices are used for lifting heavy objects and carrying out tasks that require extreme concentration and expert accuracy. The robotic arms are often used for industrial and nonindustrial purposes. Robotic arms by definition have multiple degrees of freedom that must be all directed in a kind of electromechanical ballet. In fact, the feedback required to motivate sensitive robotic grippers — ones responsive enough to the environment to be of practical use — is something of a new possibility: Therefore, it’s been many years since the first practical grippers went into production for real industrial applications. Modern industrial arms have increased in its capability and performance through micro-controllers and programming developments, improved mechanisms, sensing, and drive systems, Which has resulted in an enormous shakeout in the robotic industry .Our robotic arm was able to achieve a full pick and place mechanism that has the ability to replicate a manual pick and place procedure. Furthermore this robotic arm has the ability to find an object which is randomly placed somewhere in its range and pick and place the object as per the user inputs which are fed into the system through a key pad and LCD interface. Additionally it is capable of rotating the picked object in-order to get a desired orientation. The workspace or the range of reach would be cylindrical in shape or would be a segment of a cylinder depending on the mechanical factors.

2.0 BACKGROUND AND LITERATURE REVIEW

2.1 A Literature Review on Robotic Arms\

Robotic arm is a type of mechanical arm, usually programmable, with similar functions to a human arm [1]. Types of robot arms depend on their range, working capability and reach. Cartesian robot is used for pick and place work, plotting and handling arc welding. Its range is mostly 2 dimensional. Cylindrical robot is also used for the above mentioned working categories, but since it operates in a cylindrical co-ordinate system, it can be used to do the operations more precisely and accurately, furthermore it also has a wider reachable range. Spherical robot works on the polar coordinate system. SCARA robot is mainly used for pick and place work. It has to parallel rotary joints to provide flexibility in a plane. Then for a three dimensional reach it is usually combined with other mechanisms. Articulated robot has three rotary joints. Parallel robots are used in the mobile platform handling cockpit flight simulators. It is a robot whose arms have concurrent prism shaped or rotary joints. Anthropomorphic robot - This resembles a human[1] hand, with independent fingers and thumbs.

2.2 A Literature Review on Robotic Arm Grippers

Gripper is an end-of-arm device often used in material handling applications. Generally, the gripper is a device that is capable of generating enough grip force to retain an object while the robot performs a task on the part such a pick-and-place operation. Any gripper must be capable of performing the task of opening and closing with a prescribed amount of force over many years of daily operation The most commonly used grippers are finger grippers[2], [3]. These grippers generally have two opposing fingers or three fingers like a lathe chuck. The fingers are driven together such that once gripped any part is centered in the gripper. This gives some flexibility to the location of components at the pick-up point. Two finger grippers can be further split into parallel motion or angular motion fingers. Angular jaw gripper open and close around a central pivot point, moving in an arcing motion.

An angular gripper is used when there is a need to get the tooling out of the way. The advantage for an angular gripper falls on its simple design and only requires one power source for activation. However, it has several disadvantages including jaws that are not parallel and a changing centre of grasp while closing. Meanwhile, parallel jaw gripper moves in a motion parallel in relation to the gripper's body.

A parallel gripper is used for pulling a part down inside a machine because the fingers fit into small areas better. An advantage of parallel type gripper is that the centre of the jaws does not move perpendicular to the axis of motion. Thus, once the gripper is centered on the object, it remains centered while the jaws close. Space constraints might lead to the use of parallel over angular. Figure 1(a) and Figure 1(b) shows the Parallel Jaw and Angular Jaw Gripper.

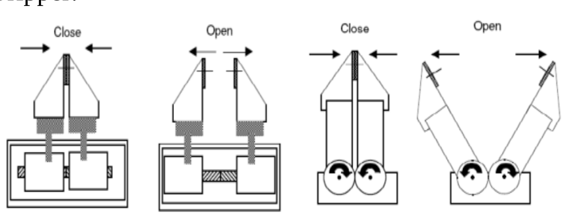


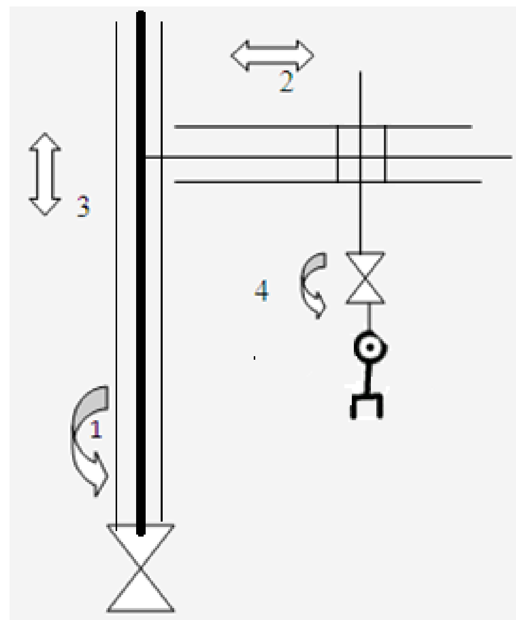
Figure 1: Parallel Jaw Gripper and Angular Jaw Gripper

For some tasks however where flexible or fragile objects are being handled, the use of either vacuum or magnetic grippers is preferable. With these, the surface of the gripper is placed in contact with the object and either a magnetic field or a vacuum is applied to hold them in contact.

3.0 DESIGN, SOLUTION AND DEVELOPMENT

3.1 Mechanical Design of Structure

The design would have a 3 dimensional reach in a cylindrical domain thus it would have these degrees of freedom as shown in Figure 2. The motor shown by number 1 is a geared motor which is capable of rotating in 360 degrees around a vertical axis. (m1). But due to other design issues with physical



obstructions it has been limited to 355 degrees.

Figure 2: Dimensions of freedom

The rail shown by number 2 and 3 are motor and belt mechanisms which make it move in horizontally and vertically respectively. (m2,m3) Here this mechanism which we have used to convert from rotational motion to linear motion is known as worm and wheel mechanism. Then number 4 is 180 degree servo which is capable of rotating in order to acquire the change in orientation (s1). Next comes the gripper and it is equipped with a geared motor to move it jaws in order to grip(m5). All the motors are controlled by the H bridge driver circuit and PWM signals and the direction signals from the microcontroller control the torque ,speed and the direction of the motors . Figure 3 shows the completed mechanical structure.

3.2 Mechanical Structure of the Gripper

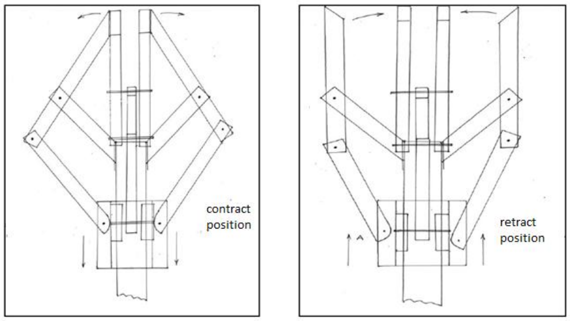


Figure 3: Gripper design in contract and retract positions

To enhance precise gripping we will use four angular jaws as pairs in opposite directions. Linear movement will be converted to an angular movement of the jaws around a pivot. Further, the jaws contract to grip the objects in converse jaws retract to release the object. Then by controlling the amount of force applied the torque on the jaw could be controlled thus the pressure applied on the object could be controlled. The following image shows the completed gripper with the gripper motor, servo motor and bearing mechanism;

Figure 4: Completed Gripper

3.3 Overall Block Diagram

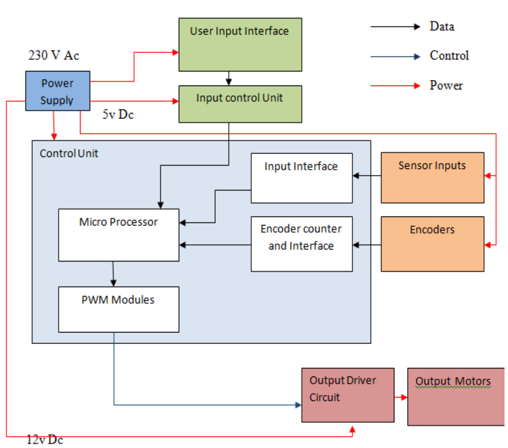


Figure 5: Overall Block Diagram

3.4 User interface with key pad and LCD:

User interface is used to capture the user inputs on destination coordinates to place the object and the desired change in orientation. It comprises of an LCD, Keypad and a dedicated microcontroller which communicates with the central controller using UART communication.

3.5 Sensors, Encoders and Feedbacks:

Here the ***ecd1,ecd2*** are Rotary encoders to get feedback on rotation and vertical height. Then ***us1*** is an Ultrasound module to sense distance to an obstruction(object) and ***us2*** is an ultrasound module for feedback on horizontal position of the gripper. ***ps1-6*** are Position Switches to denote the end positions. Further ***IRD*** is an IR sensor to confirm the presence of the object before gripping. Finally ***cs*** is a current sensing feedback from gripper motor to sense the gripping force and contact.

3.6 The Logic Design and Program Development and the Algorithm for Central Control Unit:

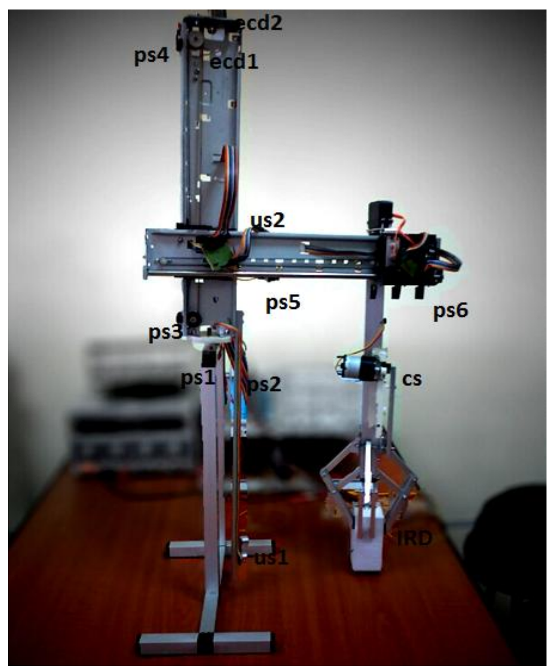


Figure 6: Completed structure with sensors

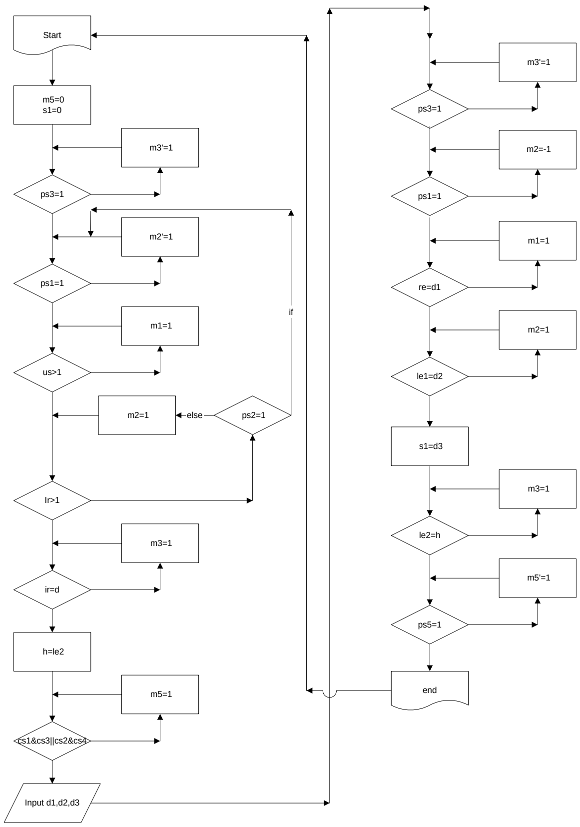


Figure 7: Control algorithm

The above algorithm was implemented in a central microcontroller as the control algorithm.

4.0 TESTING AND ANALYSIS

Test and analysis includes the entire system with the PID control algorithms for efficient and optimum movements. But up to now the testing analysis has been completed for the gripper and it would be followed by the PID implementations and testing for the overall system which has not been completed yet. At the contact of the jaw of the gripper with the object the rotation of the motor stops, thus the rotation of the gripper motor stops and the back emf would not be there anymore. Therefore there would be a sudden increment in the drained current. By the linear curve fitting of the current versus voltage curve at the contact, a straight line could be obtained which passes through the origin with a gradient of (1/Resistance).Then by plotting the maximum power margin of the motor and lower and upper voltage boundaries the operating region of the motor could be determined. The voltage boundaries are the minimum threshold voltage required to move the jaws and the maximum voltage which corresponds to the maximum supported torque from the mechanical parameters of the gripper/The maximum supported voltage from the supply, whichever occurs first, in our project the second one. All the above data could be plotted in a single plot as follows;

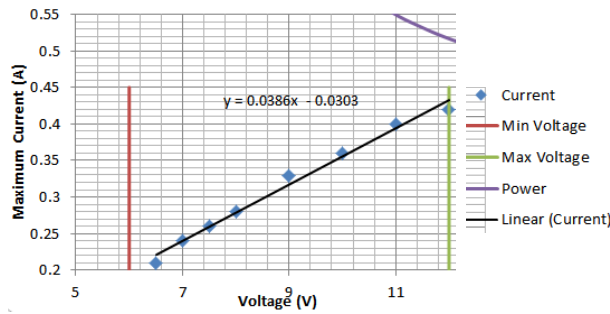


Figure 8:Operating region of motor

The current drained and the operating voltage at gripping Ig and Vg could be related as follows which depicts the ohm's law as the motor is not rotating,where the constant R corresponds to the resistance of the motor coil: Vg=0.036*Ig

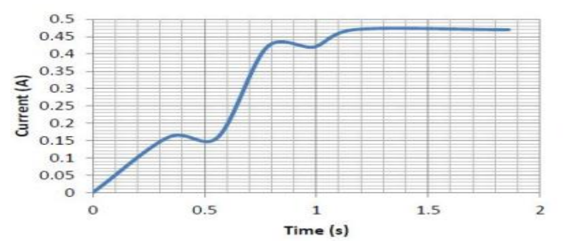


Figure 10:Variation current throughout gripping

The force applied on to the object at the point of contact would depend on the torque of the motor which depends on the current drained by the motor. A graph could be plotted experimentally to relate the voltage at the current sensing feedback with the gripping force which depends on the pulldown impedance and it was a linear relationship. So when the gripping force is specified the required feedback voltage could be obtained from the following relationship: $F=k_f V_g$ where $k_f=0.435$ Finally after obtaining the needed voltage for the gripper motor, to obtain the corresponding PWM duty ratio the following mapping has been done;

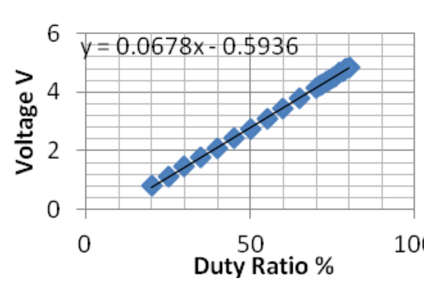


Figure 11: Voltage versus PWM

So PWM duty ratio(D) is related as: Vg=0.678D-0.59 So a PID control algorithm could be developed by targeting the required gripping force. The voltage at the current sense feedback which corresponds to the present current drain would be the present feedback variable and the Ig value corresponding to gripping force would be the reference variable. Additional modifications have been done to the PID original implementation in order to serve our task.

5.0 CONCLUSION

This is an autonomous robot arm with a three dimensional reach which could automatically detect and pick an object. Then it could place it in a destination and change the orientation as specified by the user.

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