

Kinematic Control of Pick and Place Robot Arm

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Abstract:

The robot arm is widely used in many industries and dangerous areas. Automatic control of the robotic manipulator involves study of kinematic. The kinematic problem is defined as the transformation from the Cartesian space to the joint space and vice versa. This system includes the kinematic control which is used for picking and placing the object in its workspace. There are many types of robot arm in the world of engineering. This research describes design of jointed robot arm control system using kinematic modelling. The main focus of this system is to control the end-effector of robot arm to achieve the desired position in the workspace using MATLAB programming, microcontroller and inverse kinematic modelling. The MATLAB window (GUI) is used for the inverse kinematic for the requirement data for the specified angle of the arm and displayed on the computer. The description of this system is to implement the hardware components for the moving process and to control servo motors with pulse width driving circuit. PIC and Max-232 been used to drive for the servo motors of the control system and receiving serial data from the computer. The control program is written in Mikro-C programming language.

Keywords - MATLAB GUI programming, motor driver method, inverse kinematic, control unit, serial data receiving logger.

I. INTRODUCTION

Robot arm is a mechatronic device which converts electric motors into mechanical strength and motion control theory.[2] It is usually used with servo motors to the required position of the arm, and the robot arm is used for many industries. An antenna can be used for human can be safe in the dangerous factory zone.[4]

Robotics involves elements of mechanical and electrical engineering, as well as control theory, computing and now artificial intelligence (Selig, 1992). According to the Robot Institute of America, "A robot is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks" [6]. In practice, a robot is usually an electro-mechanical machine that is guided by means of computer and electronic programming.

The most common robot used in industry today is the robot arm. These arms are used to weld, package, paint, position and assemble a host of products that we use daily. Basically a robot arm is a series of linkages that are connected in such a way that a servo motor can be used to control each joint. The controlling computer, the brain of the robot, is programmed to control the various motors on the robot in a way that allows it to perform specific tasks[8].

The robot arm can be designed in a number of different ways, the size and shape of this arm is critical to the robotic architecture of the robot. The arm is the part of the robot that positions the final grabber arm or spray head to do their pre-programmed business. If the design of the arm is too large or small, this positioning may not be possible. Many arms resemble the human arm, containing shoulders, elbows wrists and hands. The

design of the human arm is exceptional and allow for precise and complicated movement.

Robot manipulator is an essential motion subsystem component of robotic system for positioning, orientating object so that robot can perform useful task. In the field of robotics, there are five types of robot configurations that are SCARA, articulated, Cartesian, cylindrical and spherical.

In this system of robot arm is for pick and place function. This system describes about the kinematic control of jointed robot arm design using MATLAB software .At first in section I, the paper presents the introduction of the system and secondly, the system block diagram of the robot arm and system flow chart are described in section II of system description. Section III discusses about kinematic algorithm. Inverse Kinematic of robot arm control system presents in section IV. The software configuration of the robot arm represents in section V. In section VI represents simulation of robot arm and the next section represents about the experimental testing and discusses about the result. Finally, conclusion and future work is described in section VIII.

II. SYSTEM DESCRIPTION

In this system of robot arm is jointed robot arm design for pick and place function. In the hardware configuration, the system includes:

1. PIC16F628A microcontroller
2. Max-232
3. RS-232
4. Servo motors

A. System block diagram of the robot arm

The system block diagram of the robot arm is shown in Fig 1. Calibrate and test the position of servo motors by controller during arm controlling system and installation using computer and special software such as MATLAB programs and Mikro C programming.[3] The computer running the calibration software (MATLAB programs) can be connected to either the RS-232 connector on the main circuit board. The microcontroller unit (MCU), located within the printed circuit board (PCB)

Assembly mounted on the back of the inside the circuit board, controls the operation of the model PIC16F628A [7], servo controller. The logic assembly receives operating commands from the host control device or jog commands locally from the unit’s robot arm using key. These keys will move the robot’s jointed angles when the keys are in the Local position.[5]

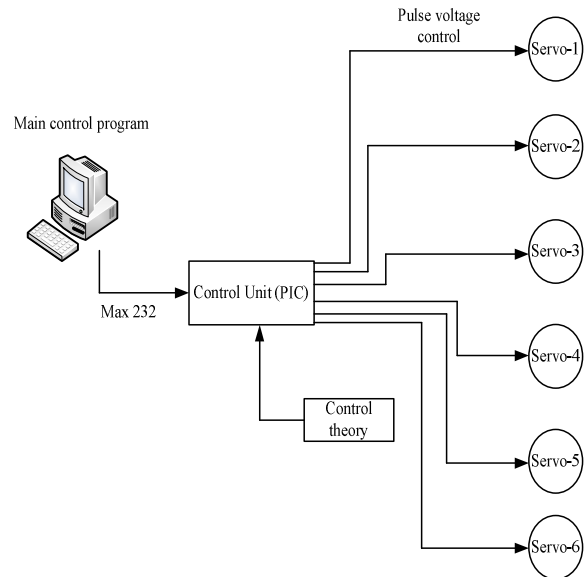


Fig. 1 Block Diagram of Robot Arm Control System

The user can calibrate the PIC16F628A using a computer connected to the RS-232 port. Programmable hardware and software limits prevent movement of the robot arm beyond physical limits. The PIC16F628A[10] saves calibration data to non-volatile memory for automatic restoration following a power outage. The PIC16F628A and RS-232 are required for PC-based robot arm controlling.[9]

B. System flowchart of the robot arm

The system flowchart of the robot system is shown in Fig 2. The user can control on the PIC16F628A to operate the arm directly or a workstation control computer via an RS-232 serial link. A serial command set is available for custom monitor and control, enabling to send required point commands to a PIC16F628A controller located up to 180 degree. Included with the unit is PC-based

calibration software that performs site calibration of the controller to the robot arm position converter.

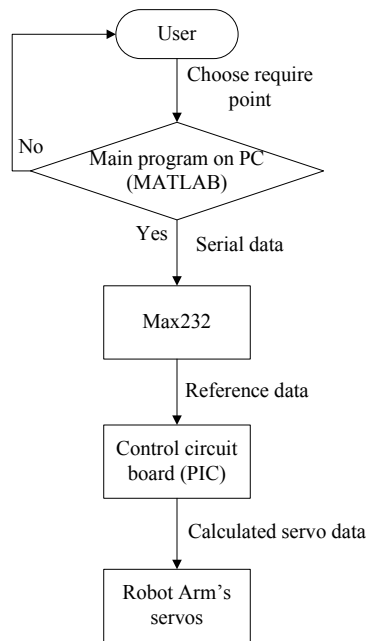


Fig. 2 System flowchart of robot arm

C. System operation

The power supply Robot Arm control system in Fig 3 is used 6V (4.5APH). DC 6V is used for all turning servo motors and also used for microcontroller and Max-232 driver.

To get voltage stability for system used capacitor (0.1uF) in the output of battery and protects the mistake of user fault by rectifier bridge diode. The positive polarity of capacitors is connected at positive voltage output of battery and negative polarity is at negative output. The power supply pin of PIC is pin.no 14 and connect with +6VDC. Pin.no 5 of controller is connected to the ground. For each servo motor, the power supply pins are connected at DC 6V and data pins are connected to the PIC controller. All data pins of the PIC controller are connected with 1k resistor for limited of Ampere. The PIC controller controls these all servo motor by generating of pulse width modulation function (PWM).

The first servo motor driving pin is connected to pin.no 18 (RA1) of pic microcontroller with specified resistor (1k). The second servo motor

driving pin is connected to pin.no 17 (RA0) of pic microcontroller. The third servo motor driving pin is connected to pin.no 13 (RB7) of pic microcontroller. The fourth servo motor driving pin is connected to pin.no 12 (RA1) of pic microcontroller. The fifth servo motor driving pin is connected to pin.no 11 (RA1) of pic microcontroller. The sixth servo motor driving pin is connected to pin.no 10 (RA1) of pic microcontroller.

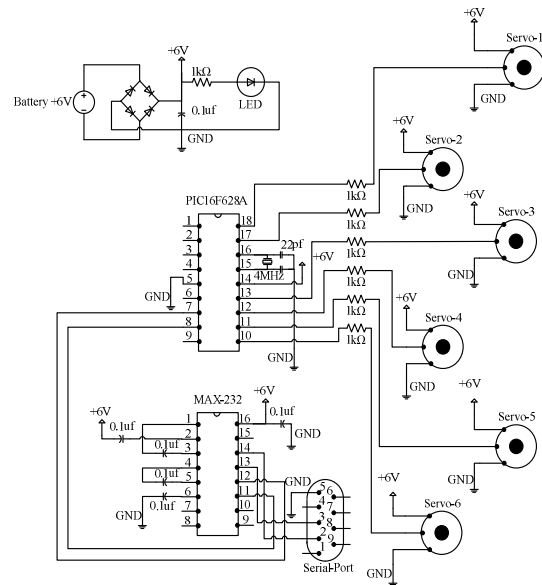


Fig. 3 Overall circuit diagram of the Robot Arm

The power supply pin of Max 232 is pin.no 16 and ground pin is pin.no 15. This driver has 5 capacitors for understand the USART serial data (TTL) from microcontroller to computer serial data. The capacitors position of Max 232 are pin.no 1 to pin.no 3, pin.no 16 to pin.no 2, pin.no 4 to pin.no 5, pin.no 6 to ground and pin.no 16 to ground. Each capacitor values are 0.1uF.

At the start of the operation in Fig 9, the user window (MATLAB) sends the serial data to the PIC controller by using USB to serial cable. In the math lap program, the user inserts the calculation theory for the robot arm position. The controller classified the angle data and produced the real data for robot arm. The controller drives the corresponding pins and moves the robot arm to the desired position.

III. KINEMATIC ALGORITHM

Kinematic is the relationships between the positions, velocities and accelerations of the link of a robot arm. The aim of the kinematics is to define position relative of a frame to its original coordinates. Using the kinematic model, a programmer can determine the configuration of input reference that should fed to every actuator so that the robot can do coincide movements of all joint to reach the desired position. Kinematics problem consists of forward and inverse kinematics. Forward kinematics is used for transferring joint variable to get end-effector position. Inverse kinematics will be applied to find joint variable from end-effector position. Fig.4 shows the forward and inverse kinematic diagram. [1].

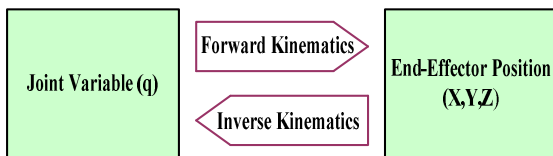


Fig. 4 Relationship between forward and inverse kinematic

Calculation the position and orientation of the hand of the robot is called forward kinematic. The forward kinematics maps the value of the joint vector to transformation matrix relating to the end-effector frame to the robot's world reference frame. With the inverse kinematics, it is possible to determine the value of each joint in order to place the arm at a desired position and orientation. The inverse solution is generally more difficult than the forward solution.

IV. ROBOT ARM INVERSE KINEMATIC

The system is used the inverse kinematic calculation to control the robot arm positioning and orientation. The inverse kinematic model calculates the joint angles to the desired position and orientation using coordinate system shown in Fig 5 and Fig 6.[11] Analytical method was used in this system to determine the correct joint angles for and object in the workspace of the robot arm. The theta1 joint angle for base rotation, theta2 joint angle for shoulder rotation and theta3 joint angles

for elbow rotation and theta4 joint angle for waist are calculated using analytical method, while the theta5 is used for gripper on and off condition. Using trigonometry relation, the following equation are getting :

$$Q = [(x^2) + (z^2)]^{(1/2)}$$

$$X = R - L3$$

$$R = (x^2) + (y^2)$$

$$a1 = \text{acos}[\frac{((L1^2) + (Q^2) - (L2^2))}{(2 * L1 * Q)}]$$

$$a2 = \text{atan2}(Z, X)$$

$$\text{Theta1} = \text{atan2}(X, Y)$$

$$\text{Theta2} = a1 + a2$$

$$\text{Theta3} = \text{acos}[\frac{((L2^2) + (L1^2) - (Q^2))}{(2 * L1 * L2)}]$$

$$\text{Theta4} = 2 * \pi - \text{theta2} - \text{theta3}$$

Theta5 is used for the gripper on at angle 30 degree and off at angle 90degree

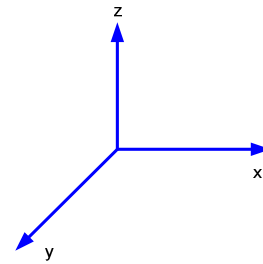


Fig. 5 Coordinate System of Robot Arm

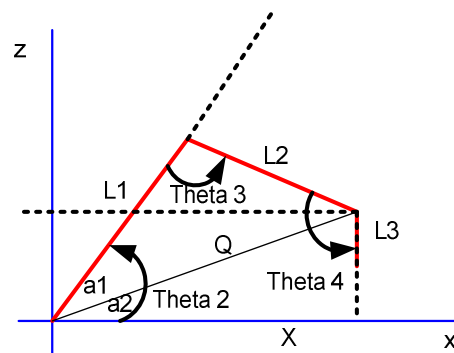


Fig. 6 xz Plane

V. SOFTWARE CONFIGURATION

The first, signed the variable which is used in specific value (e.g. int, char.....) at the program and then defined the function of pulse width modulation (PWM) and serial interfacing. The function PWM

is used to command to rotate the servo motor to specified angle. The function of serial interfacing is used to command to transfer the required data from user (PC). And then signed the used pins which are input pin or which are output pin of the propose system. For serial data, signed the USART function and received the data from interrupt program in microcontroller. Define the baud rate and bit etc. And set the data for the turning servo motors are stable at 90 degree.

infinity loop until the PC is not sent the serial data to microcontroller. If the program is received the serial data, calculate the specific angle value and corresponding servo motor. Then decide the direction of Robot arm is moved to the desired position and then the arm pick or place the specific object. And then the program is generated the necessary angle for the motor to specific angle.

VI. SIMULATION RESULT

The simulation result of this robot arm control system in Fig 8 and Fig 9 is loaded by the proteus 7.7 software. This state is known the function of the system without test in outside and suitable for test region of system.

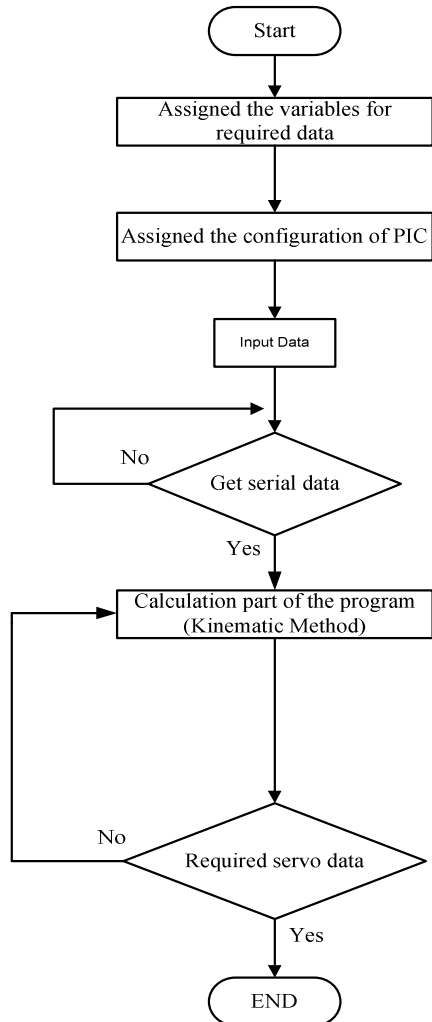


Fig. 7 Program Flowchart of Robot Arm control program

The body of the program in Fig 7 is a loop for capture the serial data which is send from the PC by user command. If the serial is been send, the program is converted the data to necessary degree and calculated the rotation angle. The loop is

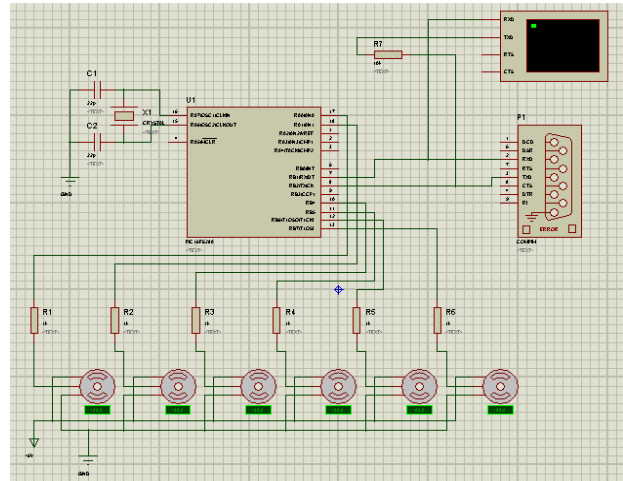


Fig. 8 Simulation of robot arm's servos

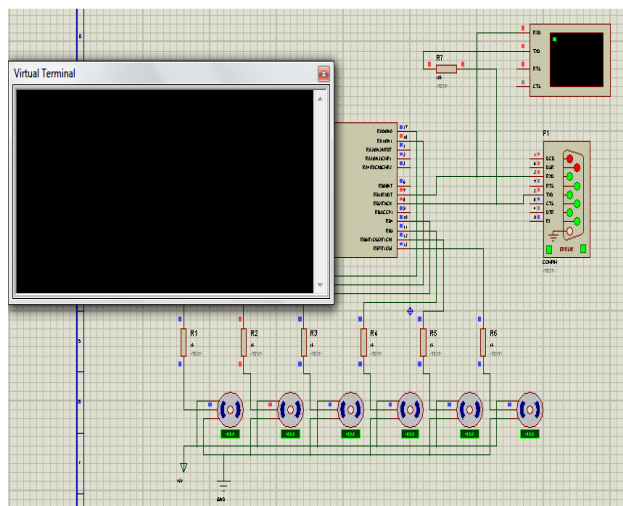


Fig. 9 Simulation of Active servos

The Fig 10 shows the simulation result of jointed robot arm using MATLAB Toolbox . In program, the system generated the simulation of the running of jointed robot arm using inverse kinematic algorithm. The simulation is tested and all the results are obtained in the form of graph shown in Fig 11.

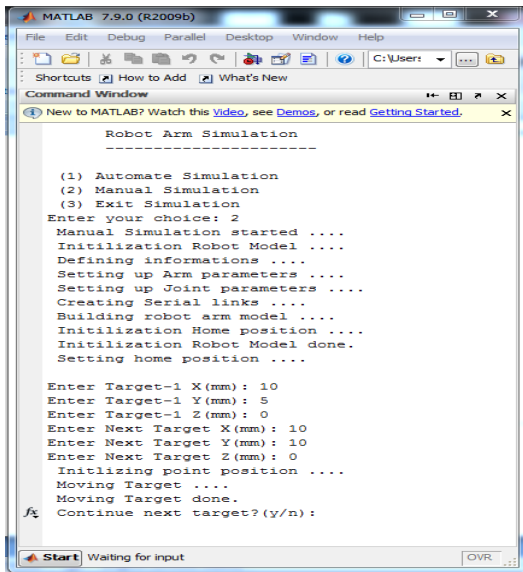


Fig.10 Simulation result of robot arm by sending command

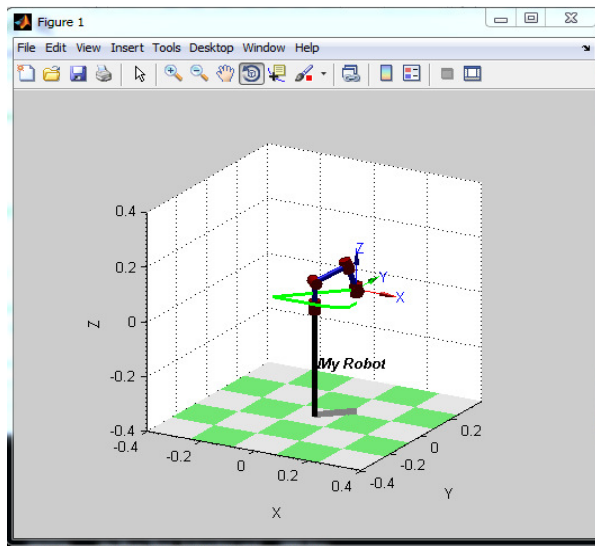


Fig. 11 Simulation result of robot arm

The graphical user interface is designed in the MATLAB as shown in Fig 12. In which, the user inputs the desired position X,Y,Z where the gripper should be. The program automatically performs the inverse kinematic calculations to obtain the joint angles and then sends a command to microcontroller to drive the robot to the specified position by communicating with RS-232 port. The following figure shows the MATLAB GUI with user interface input and output.

The user interface input are:

X axis position

Y axis position

Z axis position

Gripper

Serial port

The user interface outputs are:

Gripper angle

Wrist angle (joint 3)

Elbow angle (joint 2)

Shoulder angle (joint 1)

Base angle.

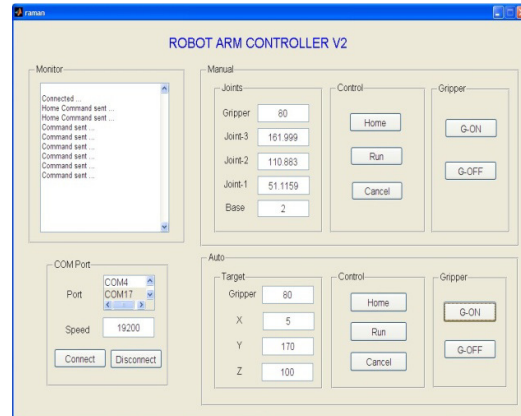


Fig. 12 MATLAB GUI user interface

The Fig 13 and Fig 14 show the testing photo of the jointed robot arm..

VII. EXPERIMENT TEST AND RESULT

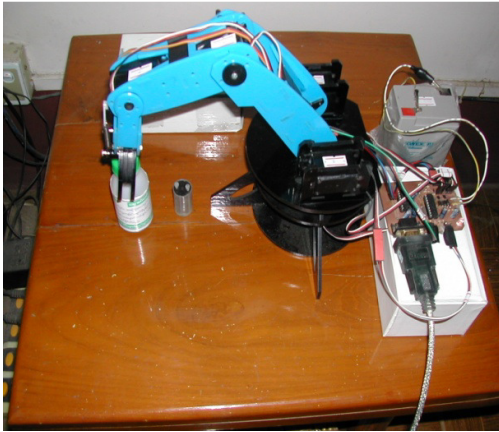


Fig. 13 Photo of testing of the Robot Arm at initial position

Several tests are carried out to reach the desired position of the end effector using its components..For the microcontroller, the tests are occurred by sending the commands from PC using MATLAB software to the microcontroller. The servos are tested sending pulse with modulation to all servos to reach right position. Different type of problems are occurred in the robot arm during testing such as wrong angle calculation, validation of the motor pulse and wrong physical measurement of the angle and position

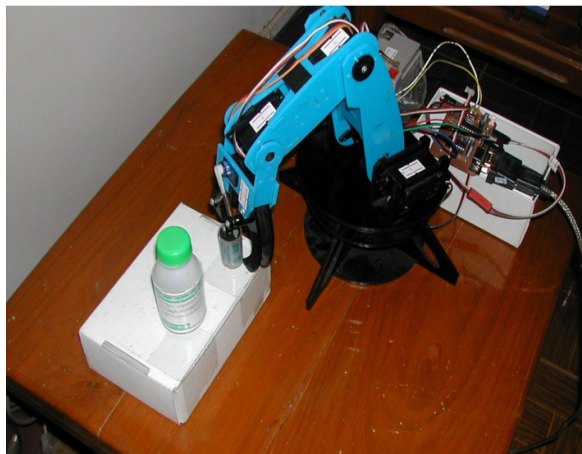


Fig. 14 Photo of testing of Robot Arm to desired position

The results from testing of the robot arm are discussed as following. The system used the six servo motors the robot arm which has limitation degree less than 180. The real range for all servo motors was found to be range as shown in table 1.

TABLE I
REAL CONDITION OF MOTOR RANGE

Motor	Angle Range
Joint1	45-135
Joint 2	30-170
Joint 3	5-170
Base	5-170
Gripper	30-90

Moreover the current consumption is depended on the load and motion of the robot arm. At the rest condition, the robot arm uses from 0 to 200mA and 200mA to 400mA is used when the robot arm is running without load. Results of the positioning accuracy are occurred in table when the robot arm moves to desired position.

TABLE II
PRECISION FOR ROBOT ARM

Axis	Positioning accuracy(+/-)
x	2cm
y	1cm
z	1cm

VIII. CONCLUSIONS AND FUTURE WORK

The hardware design and software implementation of the robot arm control system is described. The desired programming software is used in assembly for PIC controller. This system is pick and place for the specified object in good accuracy. This system can operate the several hours in industries and low power required for the Robot arm. This machine is very suitable for dangerous area in industries. The controller of the system is the best efficiency for the system, changeable data of the angle of the desired position of robot arm and nice display on computer monitor. These are reliable parts of the system for comparing to other and also it can be controlled the desired position from the computer which is implemented inverse kinematic using MATLAB interface. The system can be enhanced by including feedback encoder to drive the servo motor to reach the desired position for getting positioning accuracy. Moreover, the vision system is more popular in modern day that

can be more enhanced in precision accuracy by including that to grasp the object.

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