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Design and Kinematic Analysis of 4 Degree of Freedom Robotic Arm and its Application in Object Detection.

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ABSTRACT

In recent years, an industrial and commercial system with higher efficiency and greater performance implies great advantages of robot technology. The most common robot used in industry today is the robot arm. Kinematics analysis has been considered the initial step in the design of robotic arm. It provides information on the accurate position of each link within the robotic mechanical system. In this paper, four degree of freedom robotic arm has been designed and its kinematics analysis is done by Denavit-Hartenberg (DH) algorithm, analytic method and the Robo analyzer. The designed robotic arm is used in the application of object detection with the help of laser rangefinder which can provide the accurate and fast response in the distance measurement of the object from it. The shape of the object is detected by Hough transform algorithm and line fitting algorithm. The LPC2138 arm controller is used to control the movement of the robotics arm. The four servo motor act as an actuators for the base, arm, shoulder and elbow joints. The program is developed in C language for the rotation of the base motor, arm motor, shoulder motor and elbow motor to get the desired positions for the inverse kinematics. It is able to detect the shape of object and can be used in the noisy environmental data with help of the robotic arm. The developed system is found to work satisfactorily.

Keywords: robotic arm, kinematics analysis, laser rangefinder, shape detection.

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INTRODUCTION

Robot works in unforeseeable, hazard and unwelcoming circumstances that human cannot reach. Working in chemical or nuclear reactors is very unsafe, and a robot instead of human can be employed to avoid human risks. Robot is demarcated as the study and design of the robot system engineering [1]. The foremost reason for the progress in the usage of industrial robots is their abating cost. They are becoming most precise, most flexible and it can to do more tasks that may be dangerous or impossible for human to perform. So most industrial jobs become contenders for robotic automation. The most common robot used in industry today is the robot arm Examples are object detection, counting, defense, agriculture, medical, material handling, other industrial applications. A robot arm is a series of bonds that are connected so that a small size motor can be used to regulate each joint. The mission of a robot arm is to position an end-effector through which it interacts with its environment. The robot arms can be autonomous or controlled manually and can be used to perform a variety of tasks with great accuracy. The robot arm resembles the human arm, containing shoulders, elbows wrists and hands.[2] A. La´zaro, I. Serrano 1, J.P. Oria, implemented object shape detection method. The contour of an object detected through a self-directed robot using information obtained by ultrasonic sensors. The object sensing is carried out by using a circular inspection. A neural network model is implemented for the identification and after giving the ultrasonic data to a mathematical analysis, the 3-D reconstruction of the object is achieved. [3] Guo-Qing Wei and GerdHirzinger, implemented object detection using the laser rangefinder. The designed laser range finder and camera is mounted on the robotic arm. The image processing is used here. The triangulation based laser rangefinder is designed. It gave the distance data. The camera is capture top view of image. So 3D object is obtained. This paper explains low cost design of the robotic arm, its analysis and its application in object detection using laser rangefinder which consists of optical sensor and laser source. The shape of the object is determined with help of Hough transform and line fitting algorithm.

METHODOLOGY

Hardware Architecture

The block diagram of robotic arm with laser rangefinder is shown in Fig.1.1 Block 1 is the micro controller which is the heart of the developed system for the detection of the object. The servo motors are connected to SSC32 board capable of generating PWM is connected to LPC2138 micro controller through serial port. Block 2 consists of a laser source and sensor which is mounted on end effector (Block 6) of the robotic arm. The 650nm, 5mW red laser diode is used as the transmitter and the OPT101 sensor from Texas is used to sense the reflected light from the object by the laser beam. The laser diode and laser beam sensors are interfaced to the microcontroller kept in the block 1. The measured distance of the object is sent to the pc which is kept in the block is 3 to process the data in the PC [4].

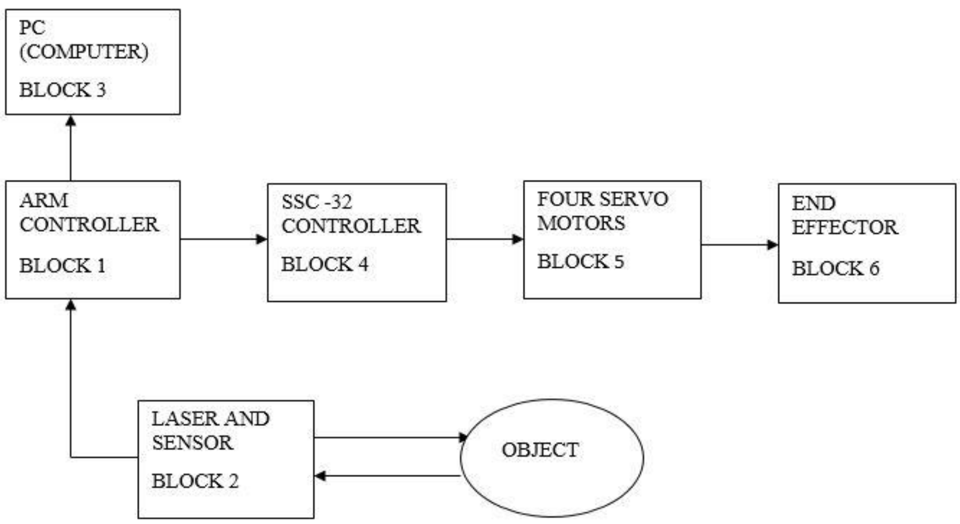

Fig 1.1: Block diagram of the Robotic system

In block 4 shows the SSC-32 is the servo controller that is given to the four servo motors (in block 5) for its pulse regulation by PWM signals. Servo controller which uses the program language to send pulse signal to motor. The pulse widths of the signal is varied from 500 to 2500 microseconds, this matches to a rotation angle of roughly 0° to 180°. A pulse width of 1500 microseconds will fix the motor at 90° in servo motor.

Design of the robotic arm

There are several consideration for designing the Robotic Arm including mechanical parts and electrical components to electronics and intelligent technology that control the overall robotic arm performance. The mechanical design such as gripper and the robotic arm body is designed as perfect to get the good performance. Robotic arm have a drive assembly and an articulated arm assembly connected to the drive assembly. The articulated arm includes a rotating base link system, a wrist link system, and a first elbow link system, shoulder link system. Four degree of freedom is given by four servo motors which are used to produce kinematics movements of the 4DOF robotic arm.

Denavit- Hartenberg Kinematics

The kinematics [5] describes the motion of the manipulator without including the forces and torque of the robotic arm. There are two kinematic problems. Forward kinematics is used to determine the end effector position with known values of joint variables. Inverse kinematics is used to calculate the joint variables with use of end effector positions. There are many methods used in kinematics. Denavit-Hartenberg [6] is the one of the best method for kinematics analysis. This method uses the 4×4 homogenous transformation matrix Fig. 3.8 which represent the transformation of points in the system. The relative position and orientation of two consecutive links, and determining a transformation matrix between them, by performing the following operations.

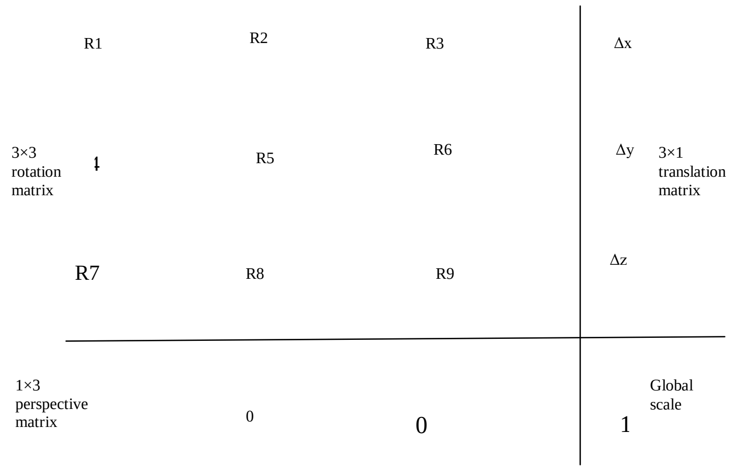

Fig. 2.2 Homogeneous transformation matrix

Design of laser rangefinder

The 650nm laser diode which is mono chromatic laser light is used. Its intensity is determined by its driver circuit. The laser is pulsed at up to tens of megahertz. The micro controller produces the PWM modulation for the laser beam [6]. So the laser light is used for further processing [7]. The photo transistor OPT101 which has 650 nm wavelength, is used as the laser receiver. The photo transistor produces the voltage with corresponding to received light [8]. In this method, the phase shift method is used [9]. The phase difference between the emitted signal from the laser beam and received signal is measured using the OPT101 photo transistor.

Hough transform algorithm

The Hough transform is a technique which is used to isolate object from the particular data set. It is commonly used for line and curve detection. It is the equation based method. It is not affected by the environmental noise. Here, the algorithm is used to detect the edge of the object using image processing techniques. The minimum and maximum point is found and threshold is calculated. Using the threshold value, the data for the object is separated. The dataset is converted into binary values. Finally the contour of the object is obtained by using the edge detection algorithm.

Line fitting algorithm

It is used only for the regular shape of object which does not contain any curve or irregular shape. The minimum and maximum is detected to calculate the threshold value in the dataset. The object is separated using the threshold value. Similar data are grouped from the dataset and maximum deviation is calculated within the grouped data. The perpendicular line is draw using the maximum deviation point. Using the drawing tool, the contour of the object is detected.

RESULT AND DISCUSSION

Output of Robo Analyzer

The output of the forward kinematics and inverse kinematics is tested using the Robo Analyzer. The real time parameters of the Robotic arm is given to the RoboAnalyzer. So the inverse and forward kinematic is calculated

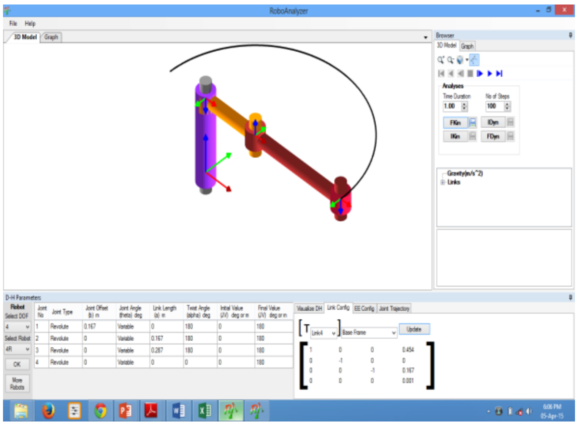

Figure 3.1 Output of RoboAnalyzer

Table 3.1 Experimental results for forward kinematics

Joint values in degrees				End effector position in meter (RoboAnalyzer)			End effector position in meters (MATLAB)			End effector position in meters (real time)		
Theta 1	Theta 2	Theta 3	Theta 4	X axis	Y axis	Z axis	X axis	Y axis	Z axis	X axis	Y axis	Z axis
0	90	90	90	0.454	0	0.167	0.412	0.089	0.164	0.450	0	0.160
45	90	90	90	0	0.454	0.167	0.012	0.312	0.164	0	0.450	0.160

Table 3.2 Experimental results for inverse kinematics

End effector position in meter			Joint values in degrees (RoboAnalyzer)				Joint values in degrees (MATLAB)			
X axis	Y axis	Z axis	Theta1	Theta2	Theta3	Theta4	Theta1	Theta2	Theta3	Theta4
.45	0	.160	0	90	90	90	0.12	89.15	88.1	90.12
0	.45	.160	45	90	90	90	37.89	87.47	89.61	86.412

The outputs of the software and hardware were similar. So the forward and inverse kinematic was obtained in different method**.**

Laser range finder output

The developed system is used to measure the distance of object from the sensor. The table 4.1 is shows the measured distance using the developed system (laser range finder) and the actual distance which is measured by the bosch DLE40 laser rangefinder.

Table 3.3 Comparison between laser range finder output and actual value

Positions of laser rangefinder		Measured distance values in mm	Actual distance measured by DLE40 laser range finder in mm	Error in percentage
X axis in deg	Y axis in mm			
-120	42	1042	1022	1.956
-128	42	1140	1030	0.97
-130	42	1134	1030	0.39
-132	42	1131	1030	0.097
-134	42	1130	1130	0
-136	42	1126	1120	0.535
-140	42	1112	1110	0.180
-142	42	1118	1105	1.09
-144	42	1105	1105	0
-146	42	1105	1105	0

Output for the Hough Transformation Algorithm

The Hough transformation algorithm is used here to find the shape of the object. The preprocessing steps are needed to get the shape of the object. The Hough transform algorithm gave very accurate results for shape detection and shown the only the contour of the object for irregular shape. Fig. 4.1 shows graph for the irregular shape object with help of preprocessing techniques.

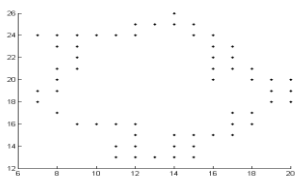

Fig. 3.2 Output of the Hough transform algorithm for irregular shape.

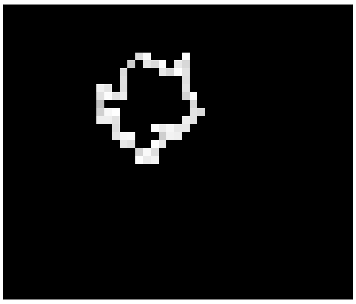

Fig. 3.3 Hough transformation output

Fig 3.2 shows the points determining the shape of the object using minimum and maximum distance values based on the sensor datasheets. The values of the dataset is converted into binary values with help of maximum and minimum distance values. From the binary values, shape of the object has been found in fig 3.3 using its coordinate points**.**

CONCLUSION

The four degree of robot arm is designed and implemented in real time. The kinematics of designed robot is obtained using the DH algorithm and its output is compared with the Robo Analyzer and Matlab. The object has been detected in the unknown environment using the laser range finder with help of robotic arm. The Hough transform algorithm has been used for the object shape detection. The extended work of this paper can be done for detection of shape of complex objects and efficient algorithms can be used for object detection.

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