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Pick and Place Robot Arm for Metal and Non-Metal Detection

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Abstract:- The pick and place robot is one of the technologies in manufacturing industries which is designed to perform pick and place operation. This system is a robot manipulator to pick metal and place it defined position and to pick non-metal and place it defined position. The system is designed that it eliminates to human error and human intervention to get more precise work. Inductive sensor is used to detect metal or nonmetal. IR sensor is used to detect that the object present to pick. Arduino Uno is used to control the system. Stepper motors are used as actuators and Easy Drivers are used to drive the actuators. The control system need 5 V power supply and drive system needs 12 V power as minimum. This manipulator is made up of aluminum. The link connections are helped by bearing. The ball bearing is used at base. The control method is very easy. In this system, the hardware is emphasized.

Keywords:- *Arduino, Metal and Non-Metal, Robot Arm, Stepper Motors.*

I. INTRODUCTION

Since many years ago, people try to replace human works with machines. A machine use power to apply forces and control movement to perform an intended action. Machine can drive by animals and people, by natural forces such as wind, water, chemical, thermal and electrical power. And then human try to place intelligence for machine to perform repeatedly job instead of human [9]. A machine is a capable of carrying out of complex series of actions automatically, especially one programmable by a computer [10].

Pick and place robot arm is used for object sorting system in [1]. Kinematic analysis, Microcontroller, servo motors, Robot arm, sorting system are studied in this research. Smart grid monitoring is used for pick and place robot in research of Dr. P. Gomathi [3]. Several application of pick and place robot arm is used in many research works [2], [3], [4]. End-effector analyses can studies in paper of Jolly shah [5].

A robot is a machine designed to execute one or more tasks automatically with speed and precision. Pick and place robot is a robot arm which is used to pick an object and place it in the specified location [2]. It can be a cylindrical robot providing motions in horizontal, vertical and rotational axes, a spherical robot providing two rotational and one linear movement, an articular robot or a SCARA (fixed robots with three vertical axes rotary arms) [6], [7]. Nowadays pick and place robots are important for human society. Many pick and place robots are used in different fields for different aims such as medical support, military defenses and even space exploration [8].

II. METHODOLOGY FOR METAL AND NON-METAL DETECTION WITH PICK AND PLACE ROBOT ARM

Nowadays, pick and place robot arm is applied to industrial applications. Methodology for pick and place robot arm can be provided by block diagram describe as below.

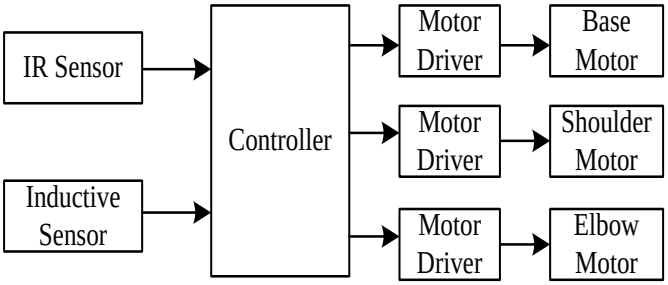

Fig 1:- Block Diagram for Metal/Non-metal Detecting with Pick and Place Robot Arm

In figure 1, block diagram of the metal/non-metal detection with pick and place robot arm is described. Power supply is the main power source of the system to provide 5 V DC to Arduino Uno. Infrared sensor is used to detect the object present or absent in desired position. To sense the metallic object, inductive sensor is applied in the system. These sensors are analog sensors and they are connected to the analog pins of Arduino. This system consists of three stepper motors which are driven by three easy motor drivers to get the require ampere.

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III. CONPONENTS SELECTION

In pick and place robot arm to detect metal/non-metal, many electronic equipment are selected. They are Arduino Uno, easy motor driver, stepper motor, infrared sensor, inductive proximity sensor.

A. Arduino Uno

A microcontroller is a high integrated functional computer system on a chip. It is contained an integrated memory and programmable input/output peripherals.

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which six can be used as PWM outputs), six analog inputs, a 16 MHz crystal oscillator, 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. The power source is selected automatically. External (non-USB) can come either from an AC to DC adapter or battery. The board can operate an external supply of 6 to 20 volts, if supply with less than 7 V, however, the 5 V pin may supply less than five volts and the board may be unstable. If using more than 12 V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts [11].

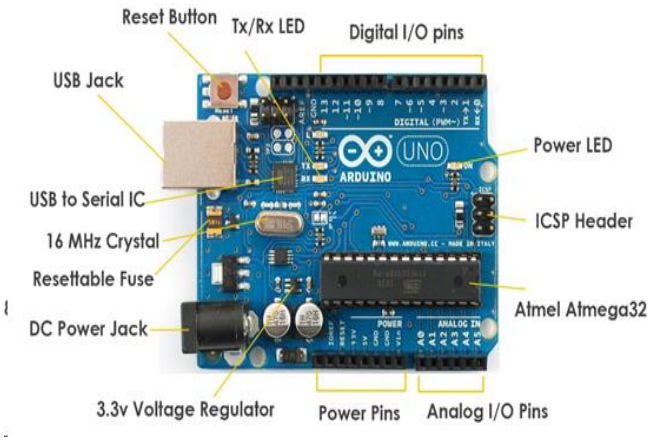

Fig 2:- Construction of Arduino Uno

B. Easy Driver Stepper Motor Driver

The Easy Driver stepper motor driver is a simple to use stepper motor driver, compatible with anything that can output a digital 0 to 5 V pulse. Easy Driver requires a 6 V to 30 V supply to power the motor and can power any voltage of stepper motor. The Easy Driver has an on board voltage regulator for the digital interface that can be set to 5 V or 3.3 V. Connect a four wire stepper motor and a microcontroller. Easy Driver drives bipolar motors, and motors wired as bipolar (i.e. four, six, or eight wire stepper motors).

Fig 3:- Easy Driver Stepper Motor Drive

C. Stepper Motor

A stepper motor is a type of DC motor that works in discrete steps. It is a synchronous brushless motor where a full rotation is divided into a number of steps. The rotor is the rotating shaft and the stator consists of electromagnets that form the stationary part of the motor.

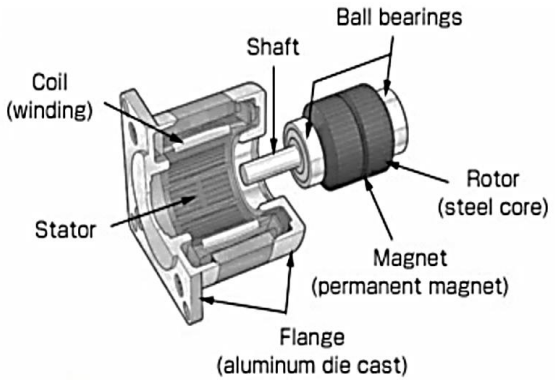

Fig 4:- Construction of Stepper Motor

Stepper motors are a class of widely used engines in many applications such as 3D printers. They are also widely used in robotics. They convert an electrical pulse in a defined angular movement called steps. The stepper motors do not require feedback loop to ensure precise movement.

D. IR Sensor (Infrared Radiation Sensor)

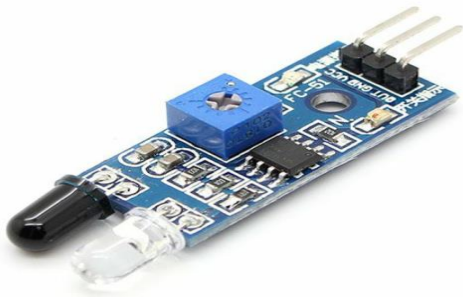

Fig 5:- IR Sensor

To receive desired objects in desired direction, an IR sensor is used in pick and place robot arm. IR sensor is worked with one, zero signal. It has two LED; infrared transmitter LED and IR receiver LED. IR transmitter LED produces infrared ray to IR receiver LED. Therefore, IR sensor is used for detecting object to start the robot program.

If IR sensor detects the object, signal LED on. And then sends the signal to Arduino Uno. IR LED will be continuously transmitted whenever an object appears IR light is reflected back and this is sensed by a sensor which in turn signals Arduino Uno to take necessary action.

E. Inductive Proximity Sensor

Fig 6:- Inductive Proximity Sensor

Inductive proximity sensor uses to detect metallic object. Inductive sensor operates under the electrical principle of inductance, where a fluctuating current induces an electromotive force (emf) in target object. Inductive sensor uses the oscillator circuit to generate a high frequency electromagnetic field.

IV. HARDWARE AND SOFTWARE IMPLEMENTATION

This pick and place robot is a robot arm which is used to pick up the metal or non-metal object and place it in the specified location. This robot arm can be a cylindrical robot make available for movement in horizontal, vertical and rotational axes.

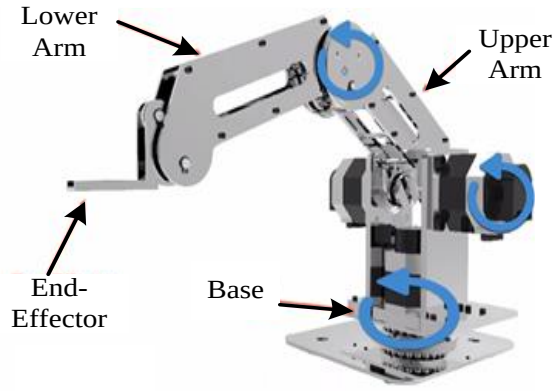

Fig 7:- Robot Arm Design Layout

The basic task of a pick and place robot arm is done by its joints. Joints are analogous to human joints and are used to join the two consecutive rigid bodies in the robot. This robot arm can be rotary joints.

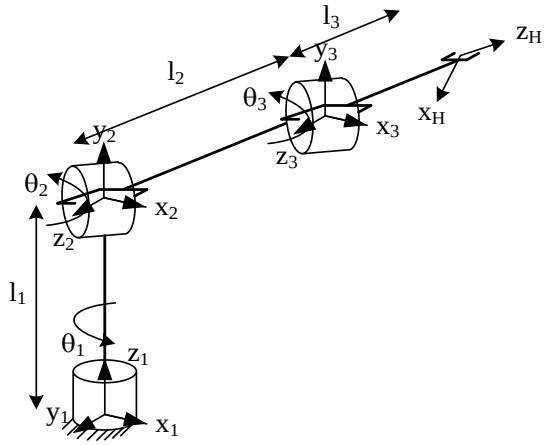

Fig 8:- Reference Frame of Robot Arm

➢ *Research Calculation of Robot Arm*

Link i	d_i	α_i	θ_i	a_i
1	l_1	90	θ_i	0
2	0	0	θ_i	l_2
3	0	0	θ_i	l_3

Table 1:- D-H Parameters used in Calculated Design

θ_i = A rotation about the z-axis
d_i = The distance on the z-axis
α_i = The angle between two successive z-axes (Joint twist)
a_i = The length of each common normal (Joint offset)

➢ *Forward Kinematic Analysis*

The forward kinematic equation of the robot can be found by substituting these parameters in to the corresponding matrices as following steps. The matrix of transformation can be established from the relation between successive frame i to i+1.

The rotation and translation of robot arm matrix is ${}^{i}A_{i+1}=H(z,\theta_i).\ H_{tran}(0,0,d_i).\ H_{tran}(a_i,0,0).H(x,\alpha_i)$

$$ {}^{i}A_{i+1} = \begin{bmatrix} \cos\theta_i & -\cos\alpha_i \sin\theta_i & \sin\alpha_i \cos\theta_i & a_i \cos\theta_i \\ \sin\theta_i & \cos\theta_i \cos\alpha_i & -\cos\theta_i \sin\alpha_i & a_i \sin\theta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

And then, the individual transformation matrices for i =1, 2 and 3 can be easily calculated. Thereafter, the total transformation ${}^{1}H_4$ is obtained from:

${}^{1}H_4 = {}^{1}A_2\ {}^{2}A_3\ {}^{3}A_4=[d_x\ d_y\ d_z]^T$

Analytically from forward kinematic method, position of the robot gripper will obtain:

$d_x=\cos(\theta_1)((l_3(\cos(\theta_2+\theta_3))+l_2\cos(\theta_2))$
$d_y=\sin(\theta_1)((l_3(\cos(\theta_2+\theta_3))+l_2\cos(\theta_2))$
$d_z=l_1+l_3(\sin(\theta_2+\theta_3))+l_2\sin(\theta_2))$

➢ *Inverse Kinematic Analysis*

There are two solutions approaches namely, geometric and algebraic used for deriving the inverse kinematics solution, analytically. There are three nonlinear equations with three unknowns to calculate the inverse kinematic. Solving these equations algebraically, requires that to know the joint variables (θ_1, θ_2 , θ_3) for a given griper position (d_x, d_y, d_z) are needed. Above equations (1) to (3), by dividing, squaring, adding and using some trigonometric formulas:

$\theta_1=\text{atan2}(dy,dx)$

$\cos\theta_3=(dx^2+dy^2+dz^2-a_2^2-a_3^2)/2a_2a_3$

$\sin\theta_3=\sqrt{(1-\cos\theta_3^2)}$

$\theta_2=\text{atan2}(dz,\sqrt{(d_x^2+d_y^2)})-\text{atan2}(a_3\cos\theta_3,a_2+a_3\cos\theta_3)$

$\theta_3=\text{atan2}(\sin\theta_3,\cos\theta_3)$

➢ *Overall Circuit Diagram*

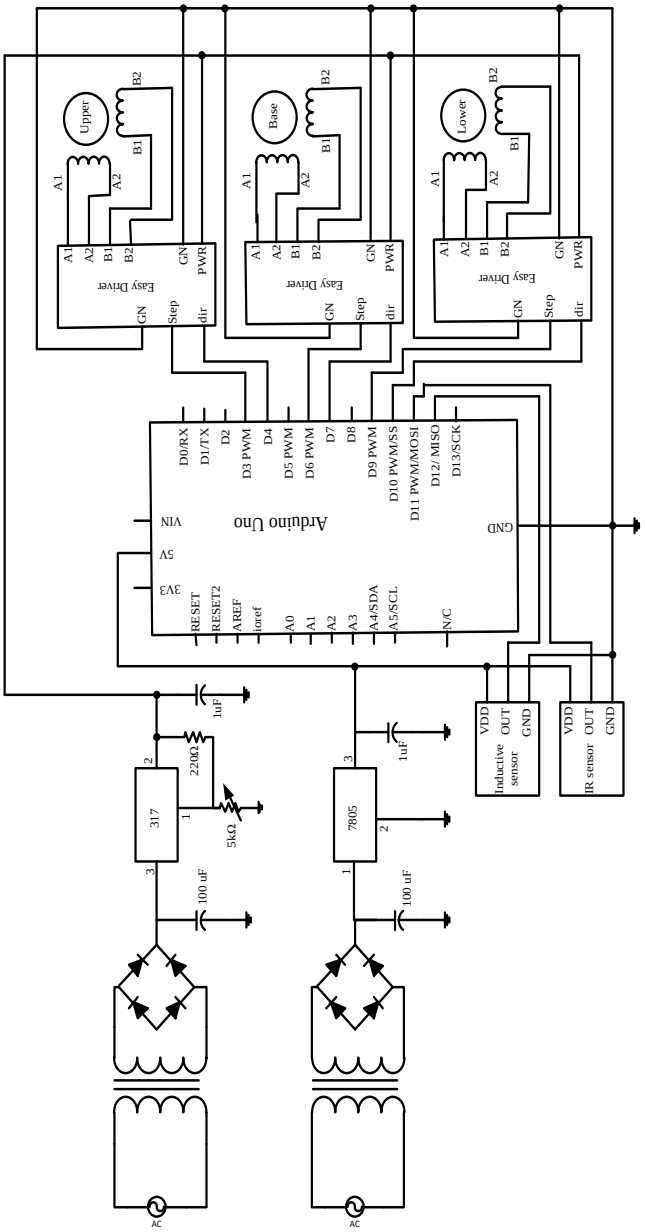

Fig 9:- Overall Circuit Diagram

The figure 9 shows the complete circuit design of metal/non-metal detection with pick and place robot arm. The full system was controlled by using stepper motors. The stepper motors are used in robotics. The stepper motor is four wires and the control signal of stepper motor is connected to the microcontroller. In this circuit design there are three motors out of which two motors are for robotic movement forward and backward, left, right and rest one motor are independently controlled for certain movement like hand movement or which can be used as a pick and place arrangement.

➢ *Process Flow Chart*

An overview of the metal/ non-metal detection with picks and place robot arm behaviors is as follows. At the start, the robot is in home position when power is supplied. After that, IR sensor will detect the object. If the object is presented in desired location, the proximity sensor will continue detect the object is metal or non-metal.

There are two conditions in this stage. The robot picks up the object and place in each desired position. And then, robot will stay at home position until the sensor detects the object. Otherwise, the program will end or power off.

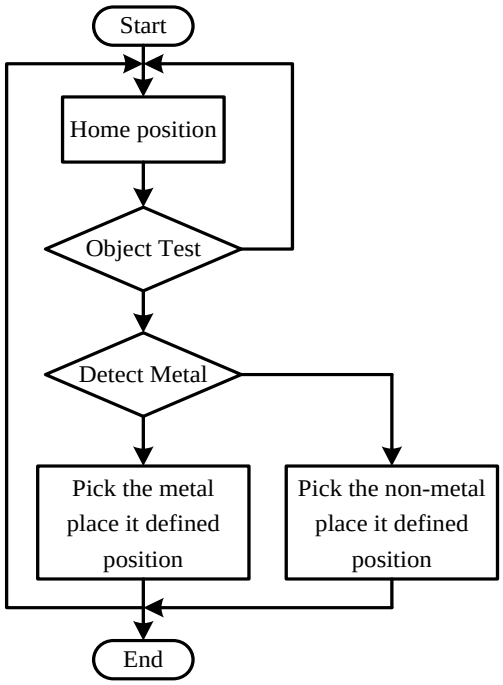

Fig 10:- Process Flow Chart

V. TEST AND RESULTS

IR sensor and inductive sensor use to receive the real time process of information from signal receiver such as sensors. In real time, block place in desired direction; it may be metal block or non-mental block. When power energizes, the IR sensor senses the desired location to check the block. If the controller gets signal from IR sensor detection, the program will start automatically. The end effector will lift the block and simultaneously the inductive proximity sensor will sense.

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The stepper motor will rotate slowly and steady to get right moving for desired directions. One stepper motor is controlled by each easy driver. Arduino Uno will control the easy driver with correct information and two directions are selected to drop the block. After testing block with proximity sensor, the end effector will drop the block in right place. Precise controls depend on suitable measure action between joints, stepper motors and end effector by robot arm.

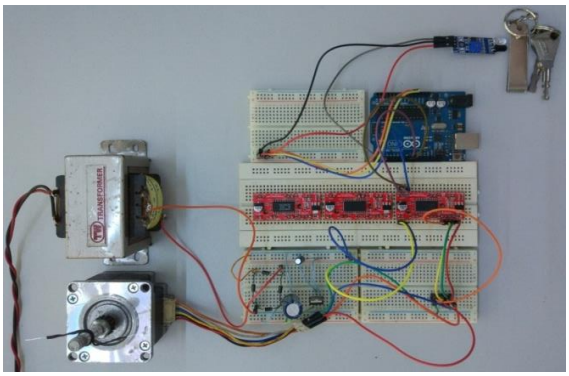

Fig 11:- Testing IR Sensors

In figure 11, IR sensor testing is shown. When IR sensor is testing, the output is resulted from stepper motor. The main power source is supplied to the Arduino Uno.

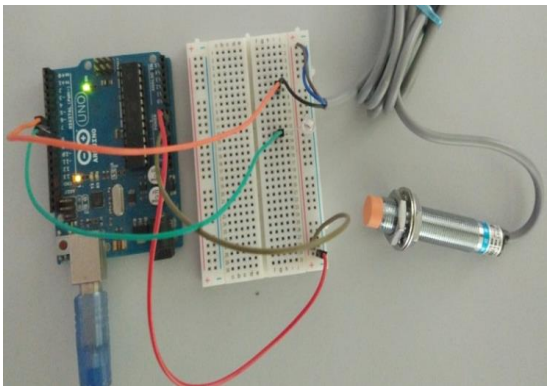

Fig 12:- Testing Inductive Sensors

Figure 12 is represented the inductive sensor testing. Inductive sensor is used to detect the metal/non-metal in this system. The required power is supported by Arduino Uno to the Inductive sensor.

Fig 13:- PCB for Overall System

In figure 13, overall circuit system is shown. In this circuit, three motor drivers are connected to Arduino Uno and the stepper motor is joined to motor driver to get the required ampere.

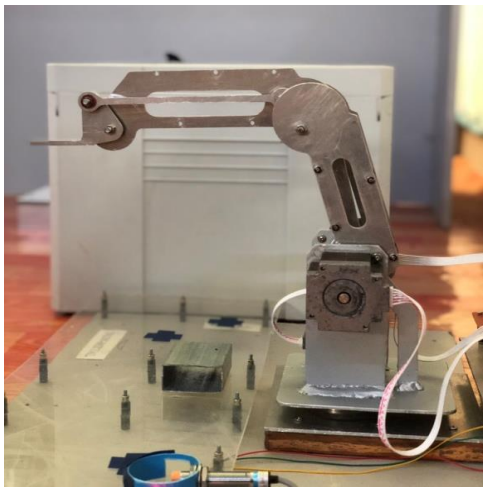

Fig. 14 Testing of Robot Arm

Figure 14 is shown the testing of the base, upper and lower arms. The base is worked when the center stepper motor is running.

VI. DISCUSSION AND CONCLUSION

There are many designs for pick and place robot arm. Some designs involve grippers to pick and place. Some designs do not involve gripper but end effector involves to pick and place the object. In this pick and place robot arm design, there is no gripper but end effector involves to pick and place.

To make the link of the robot arm, various types of materials can be chosen according to the design. Some links are made with fiber, iron, acrylic or aluminum. In this pick and place robot arm design, aluminum material is chosen to make the link of the robot. The properties of aluminum are suitable for this desired robot arm. The properties of aluminum are light weight, corrosion resistance, and electrical, thermal conductivity, and reflectivity, ductility, impermeable and odorless. Another reason for choosing the aluminum is to install bearings at every joint.

Actuators to drive the robot arm are motors. Some robot uses servo motor to drive the robot arm. Some robot uses stepper motor or DC motor with encoder. In this design, stepper motors are chosen to drive the system because the control program is written with steps to reach desired position. Firstly, the desired links and joints are drawn and simulated in the MasterCam software. And then the desired links and joints are cut on the CNC milling machine. The time is taken to install mechanical parts such as bearing, links and joints. As the aluminum material is used, the hardware is powerful in this project. The useful of ball-bearing was known to increase the torque of motor. Hardware is constructed to emphasize manipulator.

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