Design and Manufacturing of a 5 Finger Manipulating Robotic Arm

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Abstract- *The designing of a robotic arm for identifying different shapes of objects, separating and placing them at the required location has been undertaken. The robotic arm consists of a shoulder, elbow, wrist and a five-finger gripper. It performs different gripping actions using the five-finger gripper as a movable link. The workspace of our robotic arm is a hemisphere. There are two riveted joints and one circular joint. All the joints can rotate a maximum 180 degrees, because most of the servo motors cannot exceed that limit. The controller to be used is the ATMEGA 16 micro-controller on the Arduino Programming Interface.*

I. INTRODUCTION

The term robots and its arm was coined and first used by the Russian-born American scientist and writer Isaac ~~Asimov.~~ The earliest known industrial robot, conforming to the ISO definition was completed by "Bill" Griffith P. Taylor in 1937 and published in Meccano Magazine, March 1938.The crane-like device was built almost entirely using Meccano parts, and powered by a single electric motor. Five axes of movement were possible, including Grab and Grab Rotation. Automation was achieved using punched paper tape to energise solenoids, which would facilitate the movement of the crane's control levers. The robot could stack wooden blocks in pre-programmed patterns. Chris Shute built a complete replica of the robot in 1997.A robotic arm is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks. The links of such a manipulator are connected by joints allowing either rotational motion (such as in an articulated robot) or translational (linear) displacement. The links of the manipulator can be considered to form a kinematic chain. The terminus of the kinematic chain of the manipulator is called the end effector and it is analogous to the human hand. The robots movement can be divided into two general categories: arm and body motions, and wrist motions. The individual joint motions associated with these two categories are sometimes referred to by the term "degrees of freedom", and a typical industrial robot is equipped with 4 to 6 degrees of freedom. The drive system determines the speed of the arm movements, the strength of the robot, and its dynamic performance. To some extent, the drive system determines the kinds of applications that the robot can accomplish. Commercially available industrial robots are powered by one of three types of drive systems. These three systems are:

1. Hydraulic drive
2. Electric drive
3. Pneumatic drive

Work volume is the term that refers to the space within which the robot can manipulate its wrist end. In order to operate, a robot must have a means of controlling its drive system to properly regulate its motion. Commercially available industrial robots can be classified into four categories according to their control systems. The four categories are:

1. Limited-sequence robots
2. Playback robots with point-to-point control
3. Playback robots with continuous path control
4. Intelligent robots

In robotics, the term end effectors is used to describe the hand or tool that is attached to the wrist. The end effectors represents the special tooling that permits the general-purpose robot to perform a particular application. This special tooling must be designed specifically for the application. End effectors can be divided into two categories: grippers and tools. Grippers could be utilized to grasp an object, usually a work part, and hold it during the robot work cycle. A tool would be used as an end effector in applications where the robot is required to perform some operation on the work part.

II. LITERATURE REVIEW

Sharma et al. [1] designed and implemented low-cost robotic arm to help immobile patients in developing countries with object-picking tasks. The robotic arm consists of a shoulder, elbow, and wrist and five-finger gripper. It can perform different gripping actions, such as lateral, spherical, cylindrical and tip-holding gripping actions using a five-finger gripper; each finger has three movable links. The actuator used for the robotic arm is a high torque dc motor coupled with a gear assembly for torque amplification, and the five-finger gripper consists of five cables placed like tendons in the human arm. The robotic arm utilizes a controller at every link to trace the desired trajectory with high accuracy and precision.

Luo et al. [2] concluded that existing robotic hand can perform few grasp modes with proper configuration to achieve tight grasps. In this paper the problem of moving and rotating fingers towards suitable rearranged grasp modes has been attached with the aim to design a suitable mechanism with proper small size and easy-operation features. The feasibility of the proposed new design is discussed both with models and results of numerical computations. A special planetary gear mechanism has been designed to adjust the position and orientation of two fingers during hand's operation. Both pinching and enveloping grasp configurations can be achieved similarly to human hands.

The proposed scheme by Huang et al. [3] can accurately measure the relative distance between the object and robot arm using the edge detection algorithm with a camera device. The tactile sensor consists of a matrix of 64 electrodes, etched on a flexible PCB covered by a conductive rubber layer. The force sensor is an off-the shelf integrated three components micro-joystick. The analog and digital electronics is fully embedded with the sensor that is a self-standing module mounted on each finger phalange. Its process involves the colour differentiating of input visual from the camera to locate the candidate block of fitting colour requirements and thereafter define the sector. Taking visual proportion into consideration, the relative distance between target and robot arm is calculated for the arm to grip the target so that the arm is able to place object into a paper holder, where the vision of paper holder is obtained to detect its shape of hole. Borland C++ Builder 6 programming was used for the image processing in the control of robotic arm for grasping and placing.

Cannata et al. [4] presents new fully embedded tactile/force sensor system. Interaction between end effector and objects of various shapes are properly controlled only if suitable sensors are available. An innovative bio-mechatronic approach for the development of an artificial hand has been presented, with preliminary experimental results, as well as a set of software modules for sensory-motor co-ordination in robotic grasping.

Dario et al. [5] Studies on human-robot interaction, on human like movements and behaviour and its mechanisms of movement and sensory-motor learning are carried in the laboratories. The main goal of studying this paper is to manufacture human-like hands, whose main requirements are cosmetics, noiselessness and low weight and size. More in detail, this paper focuses on the control system of the hand and on the optimization of the hand design in order to obtain a humanlike kinematics and dynamics. By evaluating the simulated hand performance, the mechanical design is iteratively refined. The mechanical structure and the ratio between number of actuators and number of degrees of freedom (DOFs) have been optimized in order to cope with the strict size and weight constraints that are typical of application of artificial hands to prosthetics and humanoid robotics.

Dario et al. [6] studies innovative bio mechatronic approach for the development of an artificial hand, with experimental results, as well as a set of software modules for sensory-motor co-ordination in robotic grasping. The architecture of the hand comprises the following modules: an actuator system embedded in the under actuated mechanical, position and force sensors, 3D Force sensors distributed on the cosmetic glove an embedded control unit and (EMG) control unit to enable the amputee to control the artificial hand.
M.C. Carrozza et al. [7] this paper presents an under actuated artificial hand intended for functional replacement of the natural hand in upper limb amputees. It has been concluded in this paper that humanoid robotics can be approached by integrating human body components, such as human prostheses for upper limbs, and anthropomorphic control and behavioural schemes.

K.Hoshino et al. [8] studies have been made in five for the purpose of realization of the robot hand that is capable of conveying feelings and sensitivities by linger movement. The robot hand is capable of transmitting information promptly with comparatively high accuracy through movements. The remote control was enabled through data glove with regressive model obtained by the singular value decomposition. For the purpose of realization of the robot hand that is capable of conveying feelings and sensitivities by finger movement, studies have been made in five steps. First, a small-sized and light-weight robot hand was developed to be used as the humanoid according to the concept of extracting required minimum motor functions and mounting them to the robot. Second, simple feed forward control mechanism was designed based on speed control, and a system capable of tracking joint time-series change command with arbitrary shape was realized. Third, tracking performances with regard to sinusoidal input with different frequencies were studied for evaluation of the system thus realized, and space- and time-related accuracy were investigated. Fourth finger character movements by signal language were generated as examples of information transmission by finger movements.

M. Palankaret al. [9] Gives details of the different biological studies done with regards to the human reaching and incorporates those ideas in controlling a 9-DoF Wheelchair Mounted Robotic Arm system.

III. DESIGN AND PRINCIPLES

The design consist of the seven major parts mainly robotic arm, degree of freedom and work space, force calculation of joints, , velocity calculation, sensor, actuators and principle used for calculation of motion is inverse kinematics.

1. Robotic Arm:

Our robotic arm consists of 2 links having 2 riveted and 1 circular joints, as shown in Fig.1. It consists of 5 finger end effecter. Among the two links one link is having greater length than other. Square cross section is used for both links. The square shape cross section will guide the motors during assembly. The Material used for links is aluminium which is very light weight and very thin. Pay load for our robotic arm will be 150 to 200gms. Payload is maximum weight which our robotic arm will grasp, are bottle, ball, plastic pipe, cube, etc.

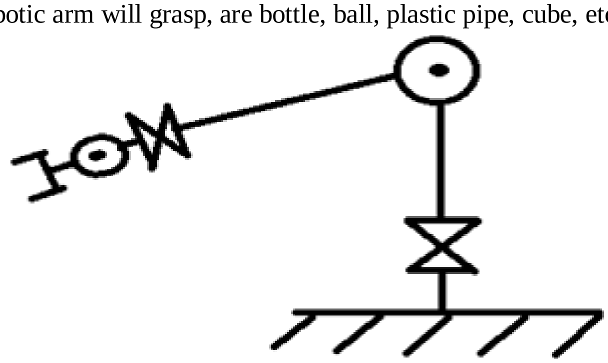

Fig. 1 Robotic arm having 2 riveted and 1 circular joint

2. Force calculation of joints

The point of doing force calculations of joints is for motor selection. You must make sure that the motor you choose can not only support the weight of the robot arm, but also what the robot arm will carry (payload).The first step is to label our FBD, with the robot arm stretched out to its maximum length.

Required parameters are:

a) Weight of each linkage
b) weight of each joint
c) weight of object to lift
d) length of each linkage

Next we do a moment arm calculation, multiplying downward force times the linkage lengths. This calculation must be done for each lifting actuator. This particular design has just two DOF that requires lifting, and the center of mass of each linkage is assumed to be Length/2 .

i) Torque about Joint 1

M1=W1*L1=0.5*10=5kg.cm
W1= 500 gm.; L1=10cm

ii) Torque about Joint 2:

M2= W1*(L1+L2) + W2*L2/2
= 0.5*(10+30) + 0.9*15= 27 kg.cm
W2=900gm; L2=30cm

3. Design of gripper

End effectors is the last part attached to the robotic arm which will grasp the object. Most end effectors available in market consist of 2 fingers. We have designed an end effectors similar to the human hand consisting of five fingers

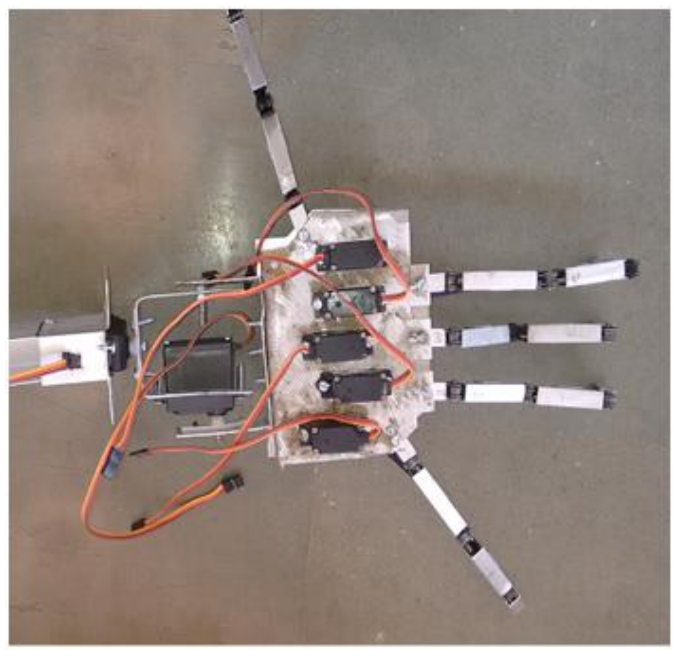

Fig. 2 Five-fingered gripper

4. Force Calculations of end-effector

i) Gripper Force,

CONSIDERING µ=0.63 (FOR PLASTIC AND FOAM)

$W=N.\ \mu.F_G \quad =9.81*0.08=5*0.63.\ F_G$

where.
W=weight of object
N= no. of fingers
µ= co efficient of friction

F_G= gripper force

Thus, F_G=0.24907 N

ii) TORQUE,

T= Length of link * F_G

T=0.09*0.24907

=0.002285 N.m

Motor Torque= 2.3 Kg.cm , which is greater than required torque hence used

=2.285 Kg.cm

iii) DEGREE OF FREEDOM,

I N OUR ARM,

(J)LOWER PAIR=06 (h)HIGHER PAIR=00

DOF=3(L-1)-2*J-h here, L= number of links =06

= 3(6-1)-2*6-0

=01

therefore, degree of freedom (DOF) of each finger is 1.

5. Fingers

Properties:

- Made of aluminium C section.
- It is very strong, light, resistant to corrosion, and affordable. Most importantly, it is very easy to cut, shape, drill, and bend.
- Each having individual DC Servo motor.

Fig. 3 Robotic Finger

Mechanism:

- Depending upon the shape of object each motor connected to fingers will be given different angle of rotation.
- Accordingly the fingers will bend and grasp different objects in anthropomorphic ways

6. Program Code

```
#include <Servo.h>
Servo myservo1;  // create servo object to control a servo
Servo myservo2;  // create servo object to control a servo
Servo myservo3; // create servo object to control a servo
Servo myservo4; // create servo object to control a servo
Servo myservo5; // create servo object to control a servo
Servo myservo6; // create servo object to control a servo
Servo myservo7;  // create servo object to control a servo
Servo myservo8;  // create servo object to control a servo
Servo myservo9; // create servo object to control a servo
int pos = 0;          // variable to store the servo position
int potpin = A0; // analog pin used to connect potentiometer
int val;
int pos1,pos2;
void setup()
{
    myservo1.attach(22); // attaches the servo on pin  to the servo object
    myservo2.attach(23);  // attaches the servo on pin  to the servo object
    myservo3.attach(24);  // attaches the servo on pin  to the servo object
    myservo4.attach(25);  // attaches the servo on pin  to the servo object
    myservo5.attach(26); // attaches the servo on pin  to the servo object
    myservo6.attach(27); // attaches the servo on pin  to the servo object
    myservo7.attach(28); // attaches the servo on pin  to the servo object
    myservo8.attach(31); // attaches the servo on pin  to the servo object
    myservo9.attach(30);  // attaches the servo on pin  to the servo object
    //initial_pos();

     val = analogRead(potpin);                // reads the value of the potentiometer (value between 0 and 1023
    delay(5000);
}

void loop()
{
    //  while(1)
    //  {
    //  holdobject();
    //  delay(5000);
    //  releasefingers();
    //    delay(5000);
    //  }
```

```
    //
    //  pick_box();
    //  while(1);
    //
    val = analogRead(potpin);           // reads the value of the
    potentiometer (value between 0 and 1023)
    pos = map(val, 0, 1023, 0, 179);
    myservo1.write(179 - pos);    // tell servo to go to position
    myservo2.write(pos);          // tell servo to go to position
    myservo3.write(pos);          // tell servo to go to position
    myservo4.write(pos);          // tell servo to go to position

    if(pos >= 90)
     myservo5.write(179 - pos);   // tell servo to go to position
    //  myservo6.write(pos);        // tell servo to go to position
     // myservo7.write(pos);       // tell servo to go to position
    //   myservo8.write(pos);      // tell servo to go to position
     // myservo9.write(pos);      // tell servo to go to position
}

void initial_pos(void)
{
    myservo6.write(90);       // tell servo to go to position
    myservo9.write(178);   // tell servo to go to position
    myservo8.write(178);     // tell servo to go to position
    delay(3000);
    myservo1.write(179);    // tell servo to go to position
    myservo2.write(178);   // tell servo to go to position
    myservo3.write( 178);  // tell servo to go to position
    myservo4.write(180 - 179);   // tell servo to go to position
    myservo5.write( 178);     // tell servo to go to position
    myservo7.write(90);       // tell servo to go to position
    myservo8.write(178);   // tell servo to go to position
    myservo9.write(178);    // tell servo to go to position
}

void pick_box(void)
{
    for(pos1 = 178;pos1 > 135;pos1-- )
    {
        myservo8.write(pos1);   // tell servo to go to position
        delay(150);
    }
    for(pos1 = 90;pos1 < 150;pos1++ )
    {
        myservo6.write(pos1);            // tell servo to go to
        position
        delay(150);
    }
    for(pos1 = 135;pos1 > 80;pos1-- )
    {
       myservo8.write(pos1);             // tell servo to go to
       position
       delay(150);
    }
    delay(5000);
    holdobject();
    delay(5000);
    pos1=80;  //135
    pos2=150; //90
    while(1)
    {
            myservo8.write(pos1); // tell servo to go to
            position
            myservo6.write(pos2);    // tell servo to go to
            position
            pos1++;
            pos2--;
            if(pos2 == 89)
            break;
            delay(150);
    }
    for(pos1 = 180;pos1 > 90;pos1-- )
    {
            myservo9.write(pos1);        // tell servo to go
            to position
            delay(150);
    }
    pos1=135;  //80
    pos2=90; //150
    while(1)
    {
            myservo8.write(pos1);       // tell servo to go
            to position
            myservo6.write(pos2);       // tell servo to go
            to position
            pos1--;
            pos2++;
            if(pos2 == 150)
            break;
            delay(150);
    }
    releasefingers();
    delay(5000);
    myservo8.write(178);       // tell servo to go to
    position
    delay(3000);
    initial_pos();
  }
void pick_ball(void)
{
}
void pick_bottle(void)
{
}
```

```
void holdobject(void)
{
    for(pos1 = 179;pos1 > 0;pos1-- )
    {
        myservo1.write(pos1);    // tell servo to go to position
        myservo2.write(pos1);    // tell servo to go to position
        myservo3.write( pos1);   // tell servo to go to position
        myservo4.write(180 - pos1);    // tell servo to go to position
        myservo5.write( pos1);   // tell servo to go to position
        delay(50);
    }
}

void releasefingers(void)
{
    pos1 = 179;
    {
        myservo1.write(pos1);          // tell servo to go to position
        myservo2.write(pos1);          // tell servo to go to position
        myservo3.write( pos1);         // tell servo to go to position
        myservo4.write(180 - pos1);    // tell servo to go to position
        myservo5.write( pos1);         // tell servo to go to position
        delay(50);
    }
}
```

7. Observations and Results

Table 1. Result Table

Parameters	Robotic Arm	Manual Labour
Cost	High	Low
Productivity	High	Low
No. of Supervisor	Less	More
Labor Cost	Less	More
Floor Space	More	Less
Degree of Safety	Low	High
Maintenance	More	Less
Efficiency	More	Less

- The arm has been designed and manufactured as per the requirement.
- Material for the arm was selected as Aluminium which is light in weight, corrosion resistance, and recyclability.
- Use of bought out parts makes the whole assembly economical.
- Transportation is easy due to light weight and compactness.

IV. CONCLUSION

In our project we design robotic arm which is used in industries for grasping different shapes of objects and placing them at the required location. It performs different gripping actions using the five-finger gripper with help of arduino. As per the results we can conclude that the arm is very user friendly, ergonomically advanced and aesthetically sound with the best outcome that would lead to enhanced working of the energy producing device.

V. SUMMARY AND FUTURE SCOPE

Equipping the robotic arm with tactile sensors, proximity sensors so that the robot can perform tasks more efficiently. The robotic arm can be designed to perform any desired task such as welding, gripping, spinning etc., depending on the application. For example robot arms in automotive assembly line perform a variety of tasks such as wielding and parts rotation and placement during assembly. In space the space shuttle Remote Manipulator System have multi degree of freedom robotic arms that have been used to perform a variety of tasks such as inspections of the Space Shuttle using a specially deployed boom with cameras and sensors attached at the end effector. The robot arms can be autonomous or controlled manually and can be used to perform a variety of tasks with great accuracy. The robotic arm can be fixed or mobile (i.e. wheeled) and can be designed for industrial or home applications. Robotic hands often have built-in pressure sensors that tell the computer how hard the robot is gripping a particular object. This keeps the robot from dropping or breaking whatever it's carrying. Other end effectors include blowtorches, drills and spray painters. This improves their performance. In medical science: "Neuroarm" uses miniaturized tools such as laser scalpels with pinpoint accuracy and it can also perform soft tissue manipulation, needle insertion, suturing, and cauterization.

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