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Design and Manufacturing of Low Cost SCARA Robot

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***Abstract*— This report deals with the Design and Fabrication of a Selective Compliance Articulated Robot Arm (SCARA). SCARA robots are among the most widely used robots in the industry due to their high accuracy and inherent rigidity. Robotics is becoming popular and has achieved great success in the last few decades but automation isn't cheap so everyone cannot afford to transform his unit from manual to automatic. The main objective of this project was to develop a low-cost robotic arm that can be used for Pick and Place operations. Here controlling of the robot has been done by using NEMA 17 Stepper Motors and Arduino UNO. This robot is having 4 DOF and can be controlled by a Graphic User Interface that features both Forward and Inverse Kinematics control. By changing the program of the end-effector this robotic arm can be used in vast applications but mainly it can be used in the automatic assembly lines**

Keywords*— *SCARA, Robotics, Fabrication, Automation, Arduino, Graphic User Interface (GUI), Kinematics, Degree of Freedom (DOF).

I. INTRODUCTION

SCARA robots, developed in the early eighties, represent a breakthrough in assembly automation (Makino, 1980). The SCARA robots' performance, which included a large working area in the x-y plane, a suitable height in the z axis, and low sensitivity for load speed, positioning, and control accuracy, allowed them to be used in electronic printed circuit assembly, as well as the automotive and home appliance industries. Robotic arms used in assembly and production processes help to eliminate human error and increase production rates. SCARA configurations are known for their fast speed, low maintenance, great repeatability, and sturdy architecture. The SCARA robot is a four-degree-of-freedom manipulator. This sort of robot was created to increase the speed and repeatability of PICK & PLACE TASKS from one spot to another, as well as to speed up and improve assembly stages.

II. LITRATURE REVIEW

1. Modeling, Simulation and Analysis of SCARA Robot for Deburring of circular components by PVS Subhashini, N.V.S Raju and G. Venkata Rao

This research study describes the study of SCARA Robot for deburring operation of circular profiles. The SCARA Robot with four degrees of freedom is modeled in CAD Software. The Kinematics of Robot is also explained in the simplest way. The results of joint positions and joint velocities calculated from CAD Software are compared with results obtained from MATLAB. The mathematical modeling and its results in MATLAB are best explained through this paper.

2. Design and Fabrication of Pick and Place Robot To Be used in library by Anusha Ronaki M.Kranti

The use of robots in library is becoming more popular in recent years. The trend seems to continue as long as the robotics technology meets diverse and challenging needs in educational purpose. The prototype consists of robotic arm along with grippers capable of moving in the three axes and an ATMEGA 8 microcontroller. Software such as AVR Studio is used for programming, PROTESUS is used for simulation and PROGISP is used for dumping the program. RFID is used for identifying the books and it has two IR Sensors for detecting the path. This robot is about 4 kg in weight, and it is capable of picking and placing a book of weight one kg.'s.

3. Robot Arm Control with Arduino by Abdullatif Baba

Today, technology is developing in the same direction in line with rapidly increasing human needs. The work done to meet these needs makes life easier every day, and these studies are concentrated in robotic arm studies. Robot arms work with an outside user or by performing predetermined commands. Nowadays, the most developed field of robot arms in every field is the industry and medicine sector. Designed and realized in the project, the robot arm has the ability to move in 4 axis directions with 5 servo motors. Thanks to the holder, you can take the desired material from one place and carry it to another place, and also mix it with the material it receives. While doing this, robot control is provided by connecting to the android application via Bluetooth module connected to Arduino Nano microcontroller.

4. Design, Manufacturing, and analysis of Robotic Arm with SCARA Configuration by Kaushik Phasale, Praveen Kumar, Akshay Raut, Ravi ranjan Singh, Amit Nichat

This paper deals with the design of 4-Axis SCARA Robot. The analysis is also performed in Ansys. For experimental setup, the robot with cardboard material is made by the author. The experimental model is used to analyze the location of motors, length of links and its movements. The designing of the robotic arm is done in creo software. The animation is done with various constraints in the software. This research study also includes the manufacturing and assembly processes of the robot.

5. Design and Development of A 4–Dof SCARA Robot for Educational Purposes by Ksm Sahari and Hong Weng Khor

Robotics have become a common course in a lot of higher institutions. Although there are many robots available in the market, most of them are for industrial purposes and are costly. There is a need to develop low-cost robots for students in higher institutions to learn the elements of robotics such as design, kinematics, dynamics, sensing and control. The aim of this project is to design and develop a mechanical structure of a SCARA robot that can perform certain tasks for educational, research and exhibition purposes such as pick and place operation. The paper discusses the steps used in design and development of a 4 degree of freedom (DOF) SCARA robot which includes specification definition, conceptual design, product development, and testing. In specification definition phase, the specifications of the SCARA robot are first determined. After that, the best conceptual design of the SCARA robot is chosen after making concept evaluation in the conceptual design phase. Then, in third phase which is the product generation, the chosen design of the SCARA robot is fine-tuned. Stress analysis using finite element analysis is carried out before a prototype is developed. The direct and inverse kinematics, dynamics of the robot are then modeled. Off shelf parts are also selected based on the derived parameters from calculations. Electronic parts such as sensors and dedicated controller using low-cost microcontroller are then developed. Finally, the developed SCARA robot is tested to see whether it fits the targeted specifications.

6. Auto & Manual Control of Robotic Arm Using PLC by R. Jagan1, P. Rana Singh2, CH. Ashirvadam3, K. Navitha4

The main objective of this project is to control the Robotic Arm manually and automatically by using Programmable Logic Control (PLC) to pick the moving object on a conveyor belt. In industries highly advanced robots are used, but still the controlling is done by manually or processors like Arduino, microprocessors etc. There are several disadvantages by using these processors like micro controllers cannot work in the environments with the high levels of vibrations, corrosion, humidity, and other environmental factors. All these problems are overcome by using Programmable Logic Controller (PLC) which acts as a brain to control the robotic arm. This project focuses to create and build more compact, useful, and cheaper robotic arm to perform various functions where human is proven too dangerous to perform a specific task and also to eliminate human errors to get more precise work.

7. Review on Development of Industrial Robotic Arm by Rahul Gautam1, Ankush Gedam2, Ashish Zade3, Ajay Mahawadiwar4.

The use of industrial robots is increasing in areas such as food, consumer goods, wood, plastics, and electronics, but is still mostly concentrated in the automotive industry. The aim of this project has been to develop a concept of a lightweight robot using lightweight materials such as aluminum and carbon fiber together with a newly developed stepper motor prototype. The wrist also needs to be constructed for cabling to run through on the inside. It is expensive to change cables and therefore the designing to reduce the friction on cable, is crucial to increase time between maintenance. A concept generation was performed based on the function analysis, the specifications of requirements that had been established. From the concept generation, twenty-four sustainable concepts divided into four groups (representing an individual part of the whole concept) were evaluated.

III. METHODOLOGY

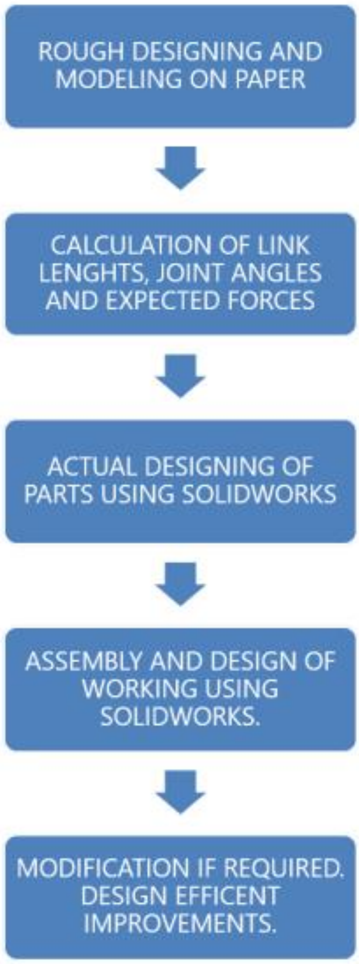

Figure 1. Rough Model

IV. DESIGN OF ROBOTIC ARM

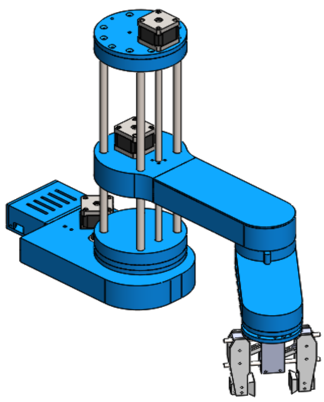

Figure 2. Assembly in SolidWorks

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The designing of robotic arm was done in SolidWorks. The various component's part drawings are created separately and by using these parts assembly was created.

Our goal for the robot was most of the parts to be 3D printed. With the specifically built pulleys, we were able to achieve a 20:1 reduction ratio for the first joint in two steps. The GT2 belts we utilized here are closed loop and have lengths of 200mm and 300mm, respectively. Two thrust bearings and one radial bearing make up the robot joints. We have a 16:1 reduction ratio for the second joint, which was produced in the same way, and a 4:1 reduction ratio for the third joint with only a single stage reduction. Because the joints are hollow, we can use them to send wires from the motors and micro switches through. There are slots on each of the belts where we may attach idler pulleys to tension them.

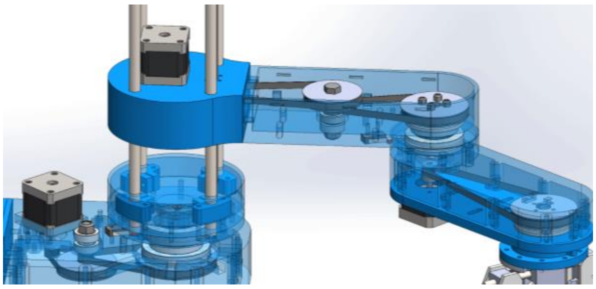


Figure 3. Joints of Robotic Arm

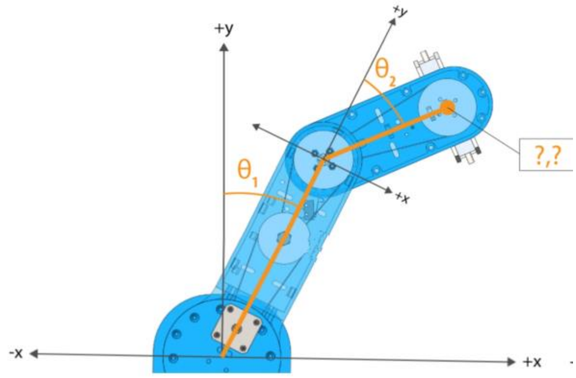
The robot gripper is driven by an MG996R servo motor and we can easily swap the gripper ends to get varied grasp sizes. The robot's Z axis is powered by an 8mm lead screw, and the entire arm assembly is supported by four 10mm smooth rods and linear ball bearings. The length of the smooth rods, which in this case are 40cm, determines the robot's height. To fit in this layout, the lead screw must be 2 cm shorter, or the Z motor can be lifted by 2 cm using spacer nuts.

V. WORKING

The robot is controlled by four NEMA 17 stepper motors and has four degrees of freedom. It also features a small servo motor for operating the end effector, or in this example, the robot gripper. The Arduino UNO board is the brain of this SCARA robot, and it's combined with a CNC shield and four A4988 stepper drivers to control the motors.

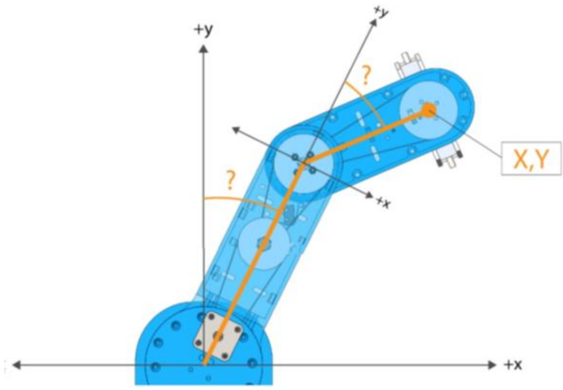
In terms of positioning and orientation, there are two approaches for controlling robots: forward and inverse kinematics. When we need to find the position and orientation of the end-effector from specified joint angles, we apply forward kinematics. Inverse kinematics, on the other hand, is used to determine joint angles for a given end-effector location.

Here are the equations we derived for forward and inverse kinematics. Position and orientation of the end effector can be calculated by joint angles Θ_1 and Θ_2 mm and the joint angles for a given position of the end-effector can be calculated by x and y.



- Forward Kinematics

$$x = L_1 \times \sin(\theta_1) + L_2 \times \sin(\theta_1 + \theta_2)$$
$$y = L_1 \times \cos(\theta_1) + L_2 \times \cos(\theta_1 + \theta_2)$$



- Inverse Kinematics

$$\theta_2 = \arccos\{(x^2 + y^2 - L_1^2 - L_2^2)/2\times L_1 \times L_2\}$$
$$\theta_1 = \arctan\left(\frac{x}{y}\right) - \arctan(L_2 \times sin\theta_2)/(L_1 + L_2 \times cos\theta_2)$$

VI. CIRCUIT DIAGRAM

We'll be using an Arduino UNO board with a CNC shield and four A4988 stepper motors. Even though it's a robot and appears to be more difficult, that's all the electronics we'll need for this project. It's worth noting that we could potentially use an Arduino MEGA in conjunction with a RAMPS 3D printer controller board instead of an Arduino UNO.

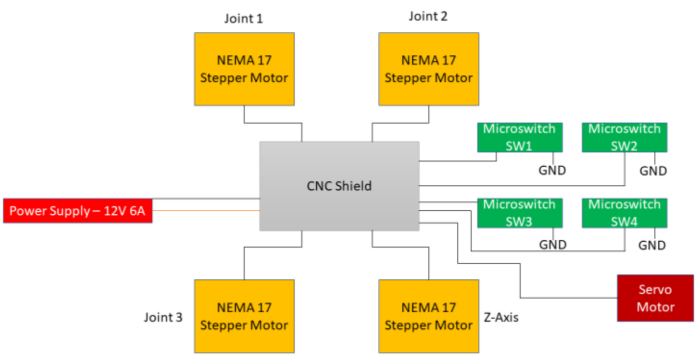


Figure 4. Circuit Diagram

VII. FABRICATION

All the parts were printed on Creality CR-10 3D printer. As previously said, the pieces are also designed to fit on a smaller 3D printer, such as the Ender3. We utilized PLA+, the blue material, for most of the parts, as well as regular PLA for the pulleys and gripper. In the slicing software, we enabled Horizontal expansion of –0.1mm for all of them. This allows the parts to have more precise dimensions and fit better with other mechanical components such as bearings, rods, and bolts.

VIII. CONCLUSION

A SCARA manipulator with four degrees of freedom was created, and it now serves as a platform for testing and studying a variety of control approaches. The parts designed were made available to the online audience so that anyone can 3d print and apply SCARA in actual form for further testing of strength, efficiency, economic viability, and use in many industrial domains. The morphology chosen for the robot's design and execution allowed it to do a variety of demonstrations and activities, which were easily and quickly programmed using an intuitive graphic interface built specifically for that purpose.

The built robotic arm may be used in a variety of ways, and any type of end-effector can be attached to the robot for various purposes. For example, we can attach a 3D printer hot end to the robot to turn it into a 3D printer or attach a laser head to turn it into a laser cutter.

IX. SPECIFICATIONS

1. Degree of Freedom: 4
2. Payload Capacity (Fully Extended): 200-250gm
3. Maximum Reach (Fully Extended): 550cm
4. Rated speed (Adjustable): 0-80 rpm
5. Hardware interface: USB
6. Control Software: Computer interface (GUI)
7. Arm 1 spin: 180°
8. Arm 2 spin: 180°
9. Arm 3 spin: 180°
10. Gripper opening: Adjustible

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