Design and Fabrication of SCARA for Image Processing in Industry

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Abstract:
The scope of our project is the design and fabrication of SCARA (Selective Compliance Articulated Robot Arm) robots optimized for image processing tasks within industrial environments. This report presents a comprehensive review of the design, control, and applications of SCARA robots, focusing on their integration with image processing technologies to enhance industrial automation. We delve into the underlying principles governing the kinematics and dynamics of SCARA robots, elucidating their operational mechanisms and capabilities. Advancements in end-effector design and sensor integration have enhanced the adaptability of SCARA robots, enabling them to tackle complex tasks in unstructured environments.

INTRODUCTION

In recent years, robotics has witnessed remarkable advancements, revolutionizing various industrial sectors and enhancing automation processes. Among these innovations, SCARA robots have emerged as pivotal tools in manufacturing, assembly, and packaging industries. Characterized by their unique kinematic structure, SCARA robots offer unparalleled precision, speed, and versatility in a wide array of applications. This paper presents a comprehensive review of the design, control, and applications of SCARA robots, with a focus on image processing applications. We delve into the underlying principles governing the kinematics and dynamics of SCARA robots, elucidating their operational mechanisms and capabilities. The versatility of SCARA robots is evident in their ability to perform intricate tasks with high repeatability and accuracy. From pick-and-place operations to image processing tasks requiring intricate manipulation, SCARA robots excel in various industrial scenarios. Furthermore, advancements in end-effector design and sensor integration have enhanced the adaptability of SCARA robots, enabling them to tackle complex tasks in unstructured environments.

In addition to exploring the hardware aspects, this review also delves into the latest developments in SCARA robot control strategies. With the advent of advanced sensing technologies and machine learning algorithms, SCARA robots can now exhibit enhanced dexterity, adaptability, and autonomy. From trajectory planning and motion control to obstacle avoidance and collaborative operation, novel control techniques are reshaping the capabilities of SCARA robots, paving the way for more efficient and intelligent automation systems.

Moreover, this review discusses emerging trends and future prospects in SCARA robotics. As industries embrace Industry 4.0 paradigms and demand for flexible, agile automation solutions grows, SCARA robots are poised to play an increasingly pivotal role in the manufacturing landscape. From small and medium-sized enterprises to large-scale production facilities, SCARA robots offer scalable solutions tailored to diverse operational requirements.

In summary, this paper aims to provide a comprehensive overview of SCARA robot design, control, and applications, highlighting their significance in modern industrial automation. By elucidating the underlying principles and latest advancements, we seek to inspire further research and innovation in the field of SCARA robotics, driving the next wave of transformative technologies in manufacturing and beyond. Its ability to work autonomously reduces human error, optimizes production time, and significantly improves overall efficiency.

LITERATURE REVIEW

[1] Sonick Sur et al SCARA Industrial Automation Robot,Assembly automation using robots has proven to be very successful Modern trends that affect manufacturing include short commodity cycles, small volumes and large variety of order which can be solved using SCARA robot. The paper tells us on the pick and place operation of SCARA robot in industrial automation and offers comparison of SCARA robot with Cartesian robots for better understanding of industry operations.

[2] See Han Tay et al A Review of SCARA Robot Control System, This paper presents a brief review of the controllers and their pros and cons when applying to the SCARA robot. The reviewed controllers include PID Control, fuzzy logic control, neural networks control, sliding mode control, impedance control, adaptive control and robust control trend of industry 4.0.

[3] Morteza Shariatee et al Safe collaboration of humans and SCARA robots, This paper presents a method to determine distance between human operator and SCARA robot using computer vision in order to provide a safe workstation for human robot collaboration. Kinect sensor is used as the input device to the system. Kinect has four streams of data among which depth data is effectively used in this approach. The measured distance is used to calculate danger index

[4] Alireza Akbarzadeh et al Design of an economical SCARA robot for industrial applications, the design process included, joint design, link design, controller design as well as selection of mechanical and electrical components. The FUM SCARA robot offers impressive performance using a PID controller, a critical trajectory in robot's workspace is traced. Results indicate low error during the fast trajectory.

[5] Junling Liu et al Four Degrees Of Freedom SCARA Robot Modelling and Simulation, SCARA robot for multivariable, nonlinear, it is difficult to verify the correctness of the model question paper for four degrees of freedom SCARA robot kinematics modeling, and then in the MATLAB environment, using Robotics Toolbox forward kinematics of the robot inverse kinematics simulated by the simulation, the observed motion of each joint SCARA robot status, verify the proposed model is correct, it is possible to achieve the desired goals

[6] Manoj Kannan et al Towards Industry 4.0: Gap Analysis between Current Automotive MES and Industry Standards Using Model-Based Requirement Engineering, the dawn of the fourth industrial revolution, Industry 4.0 has created great enthusiasm among companies and researchers by giving them an opportunity to pave the path towards the vision of a connected smart factory ecosystem.

[7] Tiago Ribeiro et al Development of a Prototype Robot for Transportation, This paper describes all the hardware and software components developed for localization and performance of the robot according to the rules.Where a robot has to successfully transport boxes from an initial warehouse to the final warehouse

[8] Batu Akan et al Towards Industrial Robots with Human like Moral, Teams consisting of humans and industrial robots are no longer science fiction. The biggest worry in this scenario is the fear of humans losing control

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and robots running amok.

[9] Z. Kuang et al Design and Analysis of Dual-arm SCARA Robot Based on Stereo Simulation and 3D Modeling, This Dual-arm SCARA robot is a robot that has been developed on the basis of a single-arm SCARA robot. It is applied to industrial production. In order to improve the robot's adaptability to complex tasks, the intelligence and the accuracy of the operation. Meanwhile, the efficiency of the robot is greatly improved.

[10] Peter A. Okeme et al Industry 4.0 Redefining Manufacuring, to establish a smart manufacturing platform that can enhance the accomplishment of smart factories is vital and desirable for modern manufacturing industries. At the moment, most conventional factories are faced with the challenge of migrating into smart factories, due to their inability to converge information and automation system to perform a real-time operation.

DESIGN CALCULATION

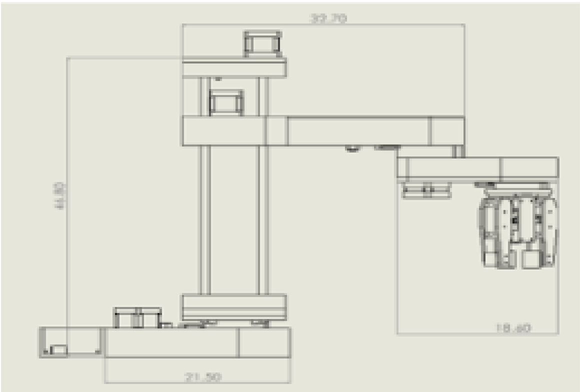

Fig 1 Proposed Diagram

The calculations fig 3.1 which are necessary to validate the design are carried out and shown here.

No.of Links, I =5;

No.of Joints, J =4;

No.of Higher pair, H=0;

Degree of freedom, n=3(I-1)-2j-h;

=3(5-1)-2(4)-0;

=12-8;

Thus, degree of freedom, n=4;

No.of rotational motion =3;

No.of prismatic motion=1;

Here our aim is to design SCARA robot with 4 degrees of freedom with 3 rotational motions and one prismatic motion.

Bending moment calculation for Links:

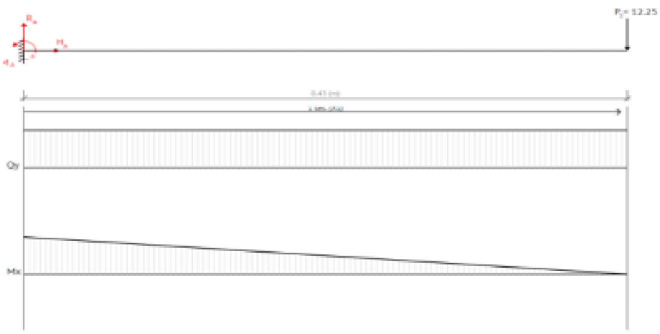

Fig 2 Bending Moment Diagram

$\sum Fx = 0$
$\sum Fy = 0$
$R_{ay} = 0$
$\sum Fy = 0$
$12.25 - R_{ay} = 0$
$R_{ay} = 12.25N$
$Ma = F * R$
$=12.25 * 0.435$
$= 532Nmm$
$Z = bd^2/6$
=0.435*0.03*0.03/6;
=65.25mm^3
By Lagrange's Equation,
L=Total Kinetic energy - Total potential energy
Link 1:
$X = l_1 \cos\theta; x^0 = -l_1 \sin\theta_1 \theta_1^0$
$Y = l_1 \sin\theta; y^0 = -l_1 \cos\theta_1 \theta_1^0$
$U^2 = x^{02} + y^{02}$
$= l_1^2 \sin^2\theta_1^{0^2} + l_1^2 \cos^2\theta_1 \theta_1^{02}$
$= l_1^2 \theta_1^2$

$K_1 = (^1/_2)(m_1 v_1^2) = (^1/_2)(m_1 l_1^2 \theta_1^2)$
$P_1 = mgl_1 \cos\theta_1$

Link 2:
$X = l_1 \cos\theta + l_2 \cos(\theta_1 + \theta_2)$
$K_2 = (^1/_2)(m_2 l_1^2 \theta_1^2) + (^1/_2)(m_2 l_2^2 (\theta_1 + \theta_2)^2) + m_2 l_1 l_2 (\theta_1 + \theta_2) \cos\theta_2 \theta_1^0$
$P_2 = mg(l_1 \cos\theta_1 + l_2 \cos(\theta_1 + \theta_2))$
$K - P = (K_1 + K_2) - (P_1 - P_2)$

$$K - P = \theta_1^2 (^1/_6 m_1 l_1^2 + ^1/_6 m_2 l_2^2 + ^1/_2 m_2 l_1^2 + ^1/_6 m_2 l_1 l_2 C_2) + \theta_2^2 (^1/_6 m_2 l_2^2) + \theta_1 \theta_2 (^1/_3 m_2 l_2^2 + ^1/_2 m_2 l_1 l_2 C_2) - m_1 g (^{l_1}/_2 S_1 + ^{l_2}/_2) S_{12}$$

By Taking Derivatives,

$$T_1 = \left(\frac{1}{3} m_1 l_1^2 + m_2 l_1^2 + \frac{1}{3} m_2 l_2^2 + m_2 l_1 l_2 C_2\right) \ddot{\theta}_1 + \left(\frac{1}{3} m_2 l_2^2 + \frac{1}{2} m_2 l_1 l_2 C_2\right) \ddot{\theta}_2 - (m_2 l_1 l_2 S_2) \dot{\theta}_1 \dot{\theta}_2 - \left(\frac{1}{2} m_2 l_1 l_2 S_2\right) \dot{\theta}_2^2 + \left(\frac{1}{2} m_1 + m_2\right) g l_1 C_1 + \frac{1}{2} m_2 g l_2 C_{12}$$

$$T_2 = \left(\frac{1}{3} m_2 l_2^2 + \frac{1}{2} m_2 l_1 l_2 C_2\right) \ddot{\theta}_1 + \left(\frac{1}{3} m_2 l_2^2\right) \ddot{\theta}_2 + \left(\frac{1}{2} m_2 l_1 l_2 S_2\right) \dot{\theta}_1^2 + \frac{1}{2} m_2 g l_2 C_{12}$$

Table 3.1 Torque calculation

Torque	Inertia Force (θ)	Centrifugal Force (θ_2^2)	Coriolis Force ($\theta_1\theta_2$)	Gravity Force (g)
T_1	2.56 x 10^{-2} Nm	0	0	1.1053
T_2	2.70 x 10^{-2} Nm	0	0	-5.25 x 10^{-1}

Dynamic Torque

$T_1 = |1.130Nm|$

$T_2 = |-0.4998Nm|$

Static Torque

$T = F * g$

$T_1 = m_1 g l_1 = 0.277 * 9.81 * 0.327 = 0.88Nm$

$T_2 = m_2 g l_2 = 0.288 * 9.81 * 0.186 = 0.525Nm$

Required torque for motor:

	T_1	T_2
T_d	1.1309 Nm	0.4998 Nm
T_s	0.88 Nm	0.525 Nm
Summation	1.983 Nm	1.0248 Nm
	20.22 Kgfcm	10.45 Kgfcm

Table 3.2 Required Torque

DESIGN MODEL

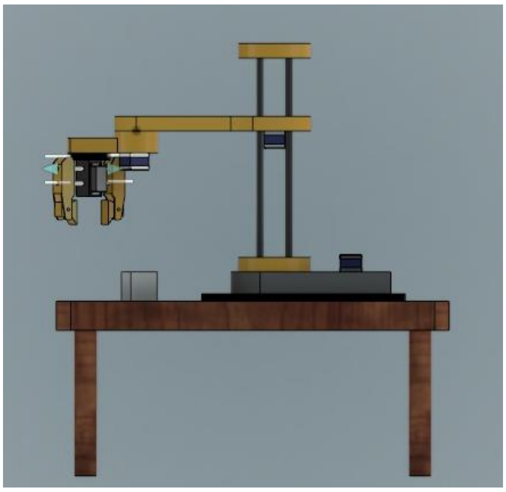

Fig 3 Front view

Fig 4 Top view

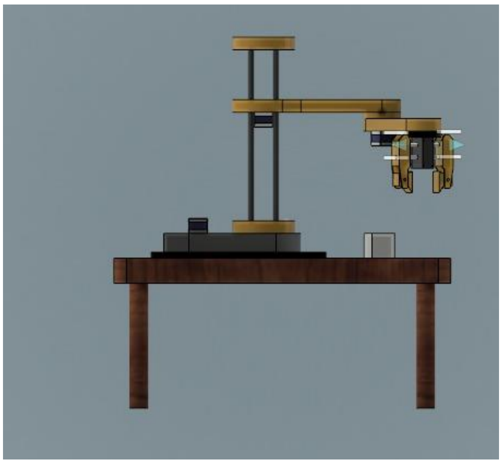

Fig 4 Side view

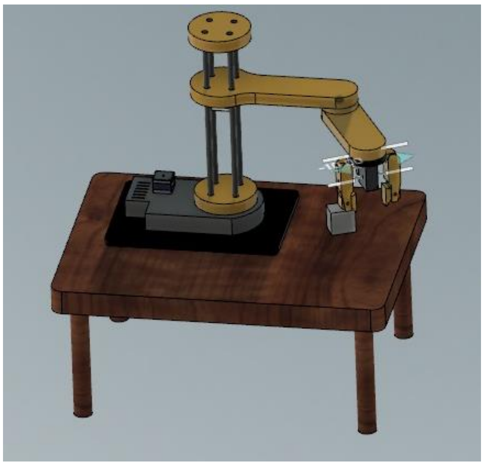

Fig 5 Isometric view

TECHNOLOGICAL STACKS

3D PRINTED PARTS

3D printing technology was utilized to fabricate key components of the SCARA robot, offering advantages of flexibility in design, rapid prototyping, and cost-effectiveness. This approach facilitated the creation of intricate geometries with precision, enhancing overall performance and functionality. 3D printed parts exhibited favorable mechanical properties, including strength and lightweight characteristics, contributing to the robot's durability and efficiency. The rapid iteration of designs enabled efficient optimization, showcasing the significant role of additive manufacturing in advancing robotics technology. Future research may further explore 3D printing's potential in optimizing robot design and performance across diverse applications.

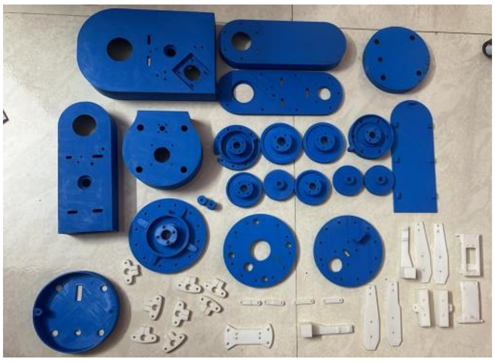

Fig 6 3D printed parts

ARDUINO UNO

Arduino is an open-source electronics platform that consists of an integrated development environment (IDE) for writing, compiling, and uploading code to a microcontroller board, usually based on the AVR or ARM architectures. Sensors, actuators, and other electrical components can be interfaced with using the digital and analog input/output pins included on Arduino boards. add to its adaptability and appeal.

Fig 7 Arduino UNO

STEPPER MOTOR

The NEMA 17 stepper motor, known for its compact size, high torque-to-size ratio, and precise control, is widely used across industries. With a frame size of 1.7 x 1.7 inches, it balances power and space efficiency, suitable for applications like 3D printers, CNC machines, and robotics. Featuring a 1.8-degree step angle and bipolar configuration, it offers precise rotational motion control and easy integration with motor driver circuits. Renowned for reliability, durability, and cost-effectiveness, the NEMA 17 stepper motor is favored by hobbyists, makers, and professionals for various motion control tasks.

Fig 8 Stepper Motor

SERVO MOTOR

A servo motor is a rotary actuator that enables precise control of angular position, velocity, and acceleration. It consists of a motor, control circuit, and feedback mechanism. Servo motors are widely used in applications requiring accurate motion control, such as robotics, automation, and industrial machinery. They excel in tasks where precise positioning or smooth, continuous motion is crucial. Servo motors operate based on input signals interpreted by the control circuit, adjusting the motor's operation to reach and maintain the desired position or velocity using feedback from a sensor. Overall, servo motors offer reliable and precise motion control, making them essential components in various electromechanical systems.

Fig 9 Servo Motor

WEBCAM

A webcam's compact design and plug-and-play functionality make it convenient for users to set up and use without extensive technical knowledge. With the rise of remote work and online education, webcams have become essential tools for staying connected and productive from anywhere. Their versatility extends to various industries, including healthcare, entertainment, and security, where they enhance communication, entertainment experiences, and monitoring capabilities.

Fig 10 Webcam

RESULTS AND DISCUSSION

The SCARA robot, designed with specific parameters and fabricated using machining and assembly techniques, demonstrates capabilities in accuracy, repeatability, speed, and efficiency. Control system integration enables precise motion control and task execution, showcasing effective coordination between hardware and software. Analysis of design choices and fabrication challenges underscores the importance of optimization for future iterations. Discrepancies between expected and observed performance highlight areas for refinement, with future research focusing on enhancing both design and control algorithms.

CONCLUSION

In conclusion, the design and fabrication of the SCARA robot presented in this study have demonstrated promising results in terms of precision, efficiency, and versatility. Through meticulous design considerations and innovative fabrication techniques, we have successfully constructed a robust system capable of meeting specified performance criteria. The integration of advanced control algorithms further enhances the robot's capabilities, enabling precise motion control and task execution. However, while this study marks a significant milestone in SCARA robot development, there remain opportunities for further refinement and optimization. Future research efforts will focus on addressing identified challenges, refining design parameters, and enhancing control strategies to broaden the scope of applications for SCARA robots in various industrial and manufacturing settings. Overall, this work contributes to the ongoing advancement of robotics technology, paving the way for more efficient and adaptable automation solutions in the future.

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