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Research Article

Robotic Arm Development for Product Segregation Application

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Abstract

A robotic arm with a SCARA (Selective Compliance Articulated Robot Arm) configuration that has two degrees of freedom was developed. Each link of the robotic arm was designed using FUSION 360, and were fabricated using suitable materials. We used 4.8-6.0V servo motors as actuators and an IR sensor and a metal detector sensor were used for the robot's functioning. Arduino UNO was used as the controlling device for functional accuracy. This paper presents the development of a robust, functional, and cost-effective robotic arm to be used in a variety of industries, including manufacturing, logistics, and healthcare. The robotic arm was developed to accurately pick up an object and place it at a desired location and orientation. This was accomplished by using advanced sensors and control algorithms that enabled the robotic arm to precisely manipulate objects in a variety of scenarios.

Keywords: *SCARA robot; robotic arm; control algorithms; product segregation.*

1. Introduction

The growth of Industry 4.0 and enabling technologies, as well as the need for mass production and IoT-based smart solutions, are major drivers of the SCARA robots market. The SCARA robot is a versatile and reliable type of industrial robot that has found wide application in manufacturing and assembly operations. With their ability to move parts through various programmed motions, these robots offer precise and consistent performance, high accuracy, and fast speeds. They are particularly well-suited for pick-and-place operations, where they can efficiently move parts from one location to another. In today's fast-paced world, the need for automation and robotics is increasing day by day. With repetitive tasks being a major part of the manufacturing industry, it becomes essential to find ways to reduce human effort and costs. This is where a cost-effective robotic arm can prove to be a game-changer.

The primary objective of this work is to develop a cost-effective robotic arm that can be used for commercial purposes, specifically in industries that require repetitive tasks. By automating these tasks, companies can not only reduce their labor costs but also increase their productivity and efficiency. Our second objective was to create a physical prototype of the robotic arm for demonstration purpose.

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This involved fabricating the various components, assembling them, and testing the robot's functionality. To achieve these objectives, the robotic arm design was optimized for cost-effectiveness without compromising its functionality and accuracy. The use of readily available and low-cost components illustrated in figure 1. helped to achieve this goal.

A mathematical model of SCARA robot including servo actuator dynamics and dynamic simulation was presented. The Lagrangian mechanics was used to derive the equations of motion. The performance of robot-actuator control system was examined through pick and place operations of cylindrical objects, and experimentally verified (Das, *et al*, 2005). A low-cost RGB color-sorting SCARA robotic arm using System-on-Chip technology was described. The design utilizes a PSoC5 chip, a light-to-frequency converter, and IR sensors to achieve color sensing. They covered the signal processing and SCARA robotic arm construction (Nkomo and Collier, 2012). A color sorting application using a robotic arm and image recognition was illustrated. The use of smart robotic arms for decision making was discussed as a potential future advancement. The potential for use in various industries such as pencil manufacturing was emphasized (Szabo and Ioan Lie, 2012). An energy-saving method for pick and place tasks of SCARA robots using adaptive elastic devices was presented. The method proposed changing the start/end points of pick and place tasks and was demonstrated through experiments using a SCARA robot with an air cylinder and vacuum pad for picking and placing chocolate pates (Hidemasa Goya *et al*, 2012).

Fig. 1 Components used in the creation of Robotic arm, Starting from left; servo motor, IR sensor, battery gripper and metal sensor

The concept of natural motion to reduce energy consumption in pick and place operations was proposed. Elastic elements are added to the mechanism to match desired motion with the natural motion of the system. Numerical optimization was used to find required spring constants and minimize torque on the motors (Juan Pablo *et al*, 2017). The development of a versatile and low-cost robotic arm to address the need for speed and accuracy in industrial processes was discussed. The autonomous robotic applications for accomplishing simple repetitive tasks efficiently, was introduced (Shah and Pandey, 2018). A SCARA robot sorting system, including kinematic analysis and development of a motion control program was developed. Off-line simulation was achieved through WPF 3D simulation technology, and real-time simulation was accomplished using OPC DA communication technology. Camera calibration and image processing were also used to obtain work piece measurements (Feng *et al*, 2019). A tool to quantify the performance of SCARA robots for pick-and-place operations, called optimal kinematic performance index (OKPI) was presented. The OKPI provides the best link lengths ratio and a map of pick-and-place points for quasi-optimal trajectories. The paper included examples related to optimization of the trajectory, design of link lengths, and selection of a commercial model, as well as a survey of commercial SCARA robots classified by their OKPI (Max Antonio *et al*, 2021). A robotic sorting system for sorting different aluminium alloys based on their alloying elements was proposed. The system consisted of a vision system, conveyor, SCARA robot, and pneumatic gripper. Experimental data was used to obtain realistic insights into the sorting efficiencies, and the initial economic analysis shown substantial potential for the proposed approach (Bart Engelen *et al*, 2022).

In our proposed robotic arm, two degrees of freedom was considered and was powered by stepper motors. Additionally, there was a small servo motor in place to control the end effector or gripper. To program the robot, we used an Arduino UNO board that was paired with a CNC shield and four A4988 stepper drivers. These components work together to control the stepper motors and ensured the robot movement as intended.

2. Methodology

The robotic arm was created in steps including modeling, fabrication, and programming, all of which were essential to achieve a functional and efficient robotic arm for various applications. Figure 2 shows the detailed representation of the entire process involved in the operation of the robotic arm. The model provides a comprehensive understanding of the different components and their functions, which is crucial for troubleshooting any issues that may arise during operation.

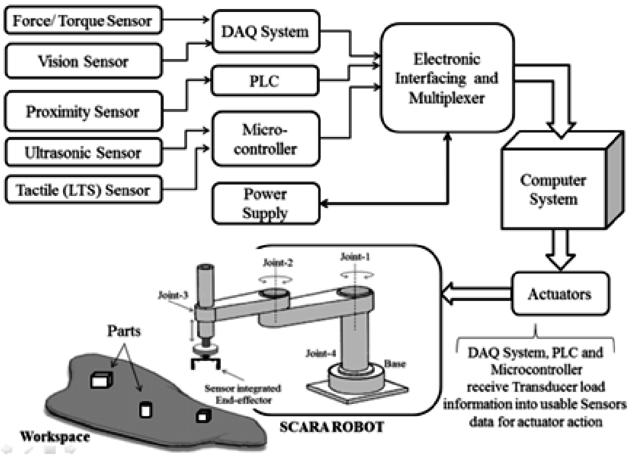

Fig. 2 SCARA robot process model

2.1 Modeling

The SCARA robot design was created using Fusion 360 software illustrated in Figure 3.

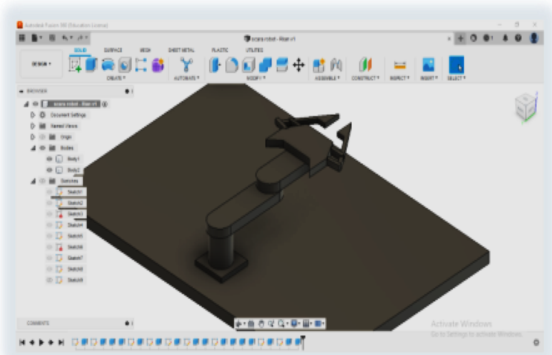

Fig. 3 Development of robotic arm in Fusion 360

This design included not only the robot's overall structure, but also the specific details of the robotic arms and their interconnections. Choosing the appropriate servo motors was also a critical aspect of this phase, as they would ultimately determine the two degrees of freedom needed for the robot's movements.

During the modeling stage, the factors such as the robot's intended use and environment was considered as well as any limitations that might impact its design.

2.2 Fabrication

After creating the model for a SCARA robot using Fusion 360, the next step was to bring the design to life through fabrication. This process involved selection of appropriate materials, tools, and techniques to construct the robot's structure and its two robotic arms with the interconnections. Due attention was paid to detail and precision in order to ensure proper robot function. High-quality materials were used as they need to be sturdy enough to support the robot's weight while also allowing for the precise movement required for its tasks. The robotic arm was assembled with care to ensure that they fit together perfectly, and that they could move seamlessly in the intended range of motion. The servo motors were also installed correctly and connected to a power source to provide the necessary energy for the robot's movements.

2.3 Programming

To program the SCARA robot, we utilized a variety of programming languages and tools. First and foremost, we wrote the firmware for the Arduino UNO board, which controls the robot's movements. This involved using the Arduino Integrated Development Environment to write code that would interface with the CNC shield and A4988 stepper drivers. We also utilized the accelstepper library, which allows for precise control of stepper motors. In addition to the firmware, we developed a Graphic User Interface (GUI) using the Processing development environment. This GUI offers intuitive and efficient control of the robot's movements. The interface includes sliders that control the angle of each joint in the robot, as well as text boxes that display the calculated X, Y, and Z positions of the end effector. The GUI also includes a button for switching between Forward and Inverse Kinematics modes. The code was carefully written to ensure that it accurately interprets the inputs received from the servo motors, allowing for smooth and precise movement. The coding was tested to ensure correct functioning and that the robot moves as expected. This testing process involved making adjustments to the code to optimize performance and to ensure that the robot meets the desired specifications. Additionally, the code may be updated or revised over time based on the usage of the robot in different applications.

3. Results and Discussion

The prototype of Robotic Arm created is illustrated in figure 4. The design can be widely used in the manufacturing industry for various applications. One of the most significant advantages of this design is its ability to provide significant stiffness in the vertical direction while allowing for flexibility in the horizontal plane. This feature allows it to perform precise and repeatable movements, making it a suitable option for assembly tasks that require high levels of accuracy and consistency.

Fig. 4 Robotic arm prototype

The robotic arm also enables to reach and manipulate objects within a defined workspace, making it ideal for applications in tight spaces or confined areas. The robot's compact design and high degree of maneuverability also make it suitable for applications that require the robot to move around obstacles or work in confined areas. In automotive manufacturing, this type of robots can be used for a variety of tasks, including assembling engine parts, painting car bodies, and handling heavy components. The design also enables it to work in harsh environments and handle moderate loads, making it an excellent option for automotive assembly lines. This kind of robotic arm finds application in the electronics industry as well. The robot's precision and accuracy make it a suitable option for assembling small components, such as circuit boards and microchips. Overall, the robotic arm designed provides an excellent balance between precision, flexibility, and speed making it a valuable tool in various industries. Its ability to perform repetitive tasks with high accuracy and consistency makes it an attractive option for automating production processes and reducing labor costs.

Conclusions

The robotic arm with two degrees of freedom that was developed in this work has proven to be a successful physical platform for testing and studying various control techniques. Despite the complexity of developing the software for the PC-Controller and electronic interface, the system has been able to function optimally and generate multiple trajectories. Additionally, after comparing the cost and performance of our robot with existing robots in the literature for the same purpose, we have confirmed its suitability for the intended application. This report demonstrates the feasibility and potential of SCARA robots in the field of robotics, particularly for testing and studying control techniques. The prototype fabricated serve as a tangible representation of our design, showcasing its capabilities to potential investors. In overall, the successful completion of this work paved the way for cost-effective automation in various industries while also providing valuable learning opportunities for aspiring engineers.

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