A project report on

3-DOF SCARA Robot for Pick And Place Application

submitted to the Department of Automation & Robotics of the KLE Technological University in partial fulfillment of the requirements for the degree of

Bachelor of Engineering

in

Automation & Robotics

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Certificate

This is to certify that project report entitled **3-DOF SCARA Robot** is a Bonafede work carried out by **AREENA, SOHAIL, SAQIB,KRISHNAVENI, MUSAIB** and **SHARAN**

in partial fulfillment for the award of degree of Bachelor of Engineering in Automation & Robotics of KLE Technological University, Hubballi during the year 2023-2024. The project report has been approved in partial fulfillment for the award if said degree as per academic.

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Name of the Examiner Signature with Date

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ACKNOWLEDGMENTS

"We would like to express our sincere gratitude and appreciation to all those who have supported and contributed to the successful implementation of SCARA robot.

First and foremost, we would like to thank our team members for their dedication, hard work, and expertise in designing, developing, and validating the system. Their commitment and collaborative efforts have been instrumental in bringing this project to fruition.

We extend our appreciation to our project advisors and mentors for their guidance, insights, and valuable feedback throughout the entire process. Their expertise and wisdom have greatly influenced the project's direction and quality.

We are also grateful to the waste industry experts and professionals who generously shared their knowledge, experience, and insights, which have greatly enriched our understanding of the trash picking domain and helped us tailor the solution to meet industry requirements.

Lastly, we would like to express our thanks to our families, friends, and loved ones for their unwavering support and encouragement throughout this journey.

Without the collective efforts and support of all these individuals and organizations, the successful implementation of trash sorting using a SCARA robot would not have been possible. We are deeply grateful for their contributions and proud to have had the opportunity to work with such remarkable individuals."

ABSTRACT

This project presents the design, development, and implementation of a 3DOF Scara (Selective Compliance Articulated Robot Arm) robot. The primary objective of the project was to create a versatile and precise robotic system capable of performing various industrial tasks with high accuracy and repeatability.

The design phase involved detailed analysis and selection of mechanical components, such as motors, gears, and linkages, to ensure optimal performance and efficiency. The kinematic model of the 3DOF Scara robot was developed, considering its workspace, range of motion, and payload capacity. Additionally, the control system was designed, integrating sensors, actuators, and feedback mechanisms for precise motion control.

The implementation phase included the fabrication and assembly of the robot, followed by the development of the control software. The software incorporated motion planning algorithms, trajectory generation, and real-time control, enabling the robot to execute complex tasks accurately.

Extensive testing and calibration were conducted to evaluate the robot's performance. Various experiments were performed to assess its positional accuracy, repeatability, and payload capacity. The results demonstrated that the 3DOF Scara robot achieved the desired accuracy levels within its specified workspace, enabling it to perform intricate tasks with precision.

The significance of this project lies in the potential applications of the 3DOF Scara robot in industrial settings. With its versatility, accuracy, and ease of integration, the robot can be utilized in assembly lines, pick-and-place operations, packaging,

and other manufacturing processes. Its compact design and affordability make it accessible to small and mediumsized enterprises, allowing them to enhance productivity and efficiency.

In conclusion, this project showcases the successful design, development, and implementation of a 3DOF Scara robot. The robot's capabilities, including high accuracy, repeatability, and versatility, position it as a valuable tool in various industrial applications. The project contributes to the advancement of robotic systems and provides a foundation for further research and development in the field of automation and robotics.

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1.INTRODUCTION

1. 1. **Introduction**

The field of robotics has witnessed significant advancements in recent years, with robotic systems being deployed across various industries to perform intricate tasks with precision and efficiency. One such application is trash picking, which involves the delicate task of selecting and retrieving trash for further processing. In this appendix, we present an overview of the implementation of trash picking using a SCARA (Selective Compliance Assembly Robot Arm) robot.

The purpose of this document is to provide a comprehensive understanding of the trash picking process and the integration of a SCARA robot into the system. We will discuss the setup, programming, testing, and safety considerations associated with this application. By following this guide, readers will gain insights into the key considerations and techniques required for successful trash picking with a SCARA robot.

In terms of system setup, we will delve into the description of the SCARA robot used for the task, outlining its capabilities and specifications. Additionally, we will explore the mechanism employed for trash picking and discuss the integration of various hardware and software components required for seamless operation. Safety considerations will also be addressed, emphasizing the importance of adhering to proper safety protocols to protect both the operators and the equipment.

The trash picking process itself will be thoroughly examined, starting with the preparation of the environment. We will then delve into the critical aspect of vision system calibration, which plays a pivotal role in accurately detecting and localizing the waste. The design and selection of the gripper mechanism will be discussed, taking into account the fragility and specific requirements of the trash. Furthermore, we will explore the grasping strategy and the sequential steps involved in picking the trash.

To enable the SCARA robot to perform trash picking effectively, programming is of utmost importance. We will provide an overview of the programming language or environment used, highlighting the kinematic model and inverse kinematics necessary for precise robot movements. The control logic and error handling mechanisms will also be covered, ensuring smooth operation and recovery in case of unexpected events. Furthermore, we will discuss the integration of the vision system and gripper with the robot's programming.

Testing and optimization are essential stages in any robotic application. We will outline the test setup, evaluation metrics, and performance evaluation methods for trash` picking. Finetuning of parameters will be discussed, allowing for optimization of the system's performance. In addition, we will explore error analysis and troubleshooting techniques to address common issues that may arise during the operation.

Safety considerations and maintenance play a crucial role in ensuring the longevity and proper functioning of the system. We will outline safety precautions for human operators working alongside the SCARA robot and provide a maintenance schedule for the robot itself. Failure detection mechanisms and preventive measures will also be covered, mitigating the risk of downtime and system failures. Guidelines for handling the gripper and vision system will be provided to ensure their longevity and accurate performance.

1. PROBLEM DESCRIPTION

Designing and development of an automatic smart trash detector and sorter recycle robot system utilizing machine learning algorithms.

The system should be capable of efficiently identifying and sorting different types of waste materials such as plastic, paper, glass, and metal to facilitate effective recycling processes. The solution should address the growing environmental concerns related to waste management and contribute towards sustainable practices by automating the sorting process and reducing contamination in recycling streams. The primary problem addressed is the development of a trash picking system using a SCARA (Selective Compliance Assembly Robot Arm) robot. The objective is to design a robotic system that can accurately detect, locate, and pick up trash with minimal damage, reducing human involvement and improving overall productivity.

The challenges associated with trash picking arise from the trash and the requirement for precise and delicate manipulation. Manual handling can lead to unintentional damage or contamination of the trash, which can have a significant impact on their value or the reliability of subsequent analyses. Additionally, the high volume and repetitive nature of trash picking make it a time-consuming and tedious task, often leading to human fatigue and decreased efficiency.

By employing a SCARA robot for trash picking, these challenges can be overcome. The SCARA robot offers the advantages of precise and repeatable movements, enabling accurate positioning and gentle handling of the trash. The robot can be equipped with a vision system for precise cocoon detection and localization, ensuring optimal picking accuracy. Additionally, automating the process reduces the dependence on manual labor, increases throughput, and minimizes the risk of errors or damage to the trash.

However, the implementation of a trash picking system using a SCARA robot requires overcoming several technical obstacles. These include developing an effective vision system capable of accurately detecting and localizing trash within the working area, designing a gripper mechanism that can securely grasp the fragile trash without causing damage, and programming the robot to perform precise and coordinated movements to achieve successful picking. Furthermore, safety considerations must be taken into account to ensure the protection of both the robot operator and the trash during the picking process.

2. MARKET STUDY

A market study of cocoon picking SCARA (Selective Compliance Articulated Robot Arm) robots would involve analyzing various aspects related to the use, demand, and potential of such robots in the market. Here are some key considerations of market study

Conducting a market study for an automatic smart trash picker involves several key components, including understanding the product, analyzing market trends, identifying target customers, assessing competitors, and estimating market size and growth potential. Here's a detailed breakdown:

1.Product Understanding

- An automatic smart trash picker is a device that autonomously collects trash from designated areas, often using technologies such as AI, robotics, and IoT. It is designed to enhance efficiency in waste management by reducing manual labor and improving cleanliness in public and private spaces.

2.Market Trends

- Growing Urbanization: Increasing urban population leads to higher waste production, necessitating efficient waste management solutions.
- Smart City Initiatives: Governments are investing in smart city projects, which include smart waste management systems.
- Technological Advancements: Improvements in AI, robotics, and IoT are making smart trash pickers more feasible and efficient.
- Environmental Concerns: Rising awareness about environmental sustainability is pushing for advanced waste management solutions.

3.Target Customers

- Municipalities and Governments: For public spaces such as parks, streets, and public buildings.
- Commercial Enterprises: Shopping malls, corporate campuses, and large facilities.
- Residential Complexes: High-end residential areas and gated communities.
- Events and Venues: Concerts, sports events, and festivals.

4.Competitor Analysis

Identify and analyze key players in the market, including their product offerings, pricing, market share, and technological innovations. Some potential competitors could be:

- Zen Robotics: Known for AI-powered waste sorting robots.

- AMP Robotics: Specializes in AI and robotics for recycling.
- Rubicon: Offers smart waste and recycling solutions.

5.Market Size and Growth Potential

- Global Waste Management Market: Estimated to grow from USD 1,612.0 billion in 2020 to USD 2,339.8 billion by 2027, driven by increased waste production and regulatory pressures.

- Smart Waste Management Market: Expected to reach USD 4.66 billion by 2025, with a CAGR of 25.68% from 2020.

6.Customer Insights and Preferences

Gather data through surveys, interviews, and focus groups to understand customer needs, preferences, and willingness to pay. Key factors to consider include:

- Efficiency and Effectiveness: How well the device collects and sorts' waste.

- Cost: Initial investment and long-term operational costs.

- Ease of Use: User-friendly interface and minimal maintenance.

Environmental Impact: Eco-friendly design and operation.

7.Go-to-Market Strategy

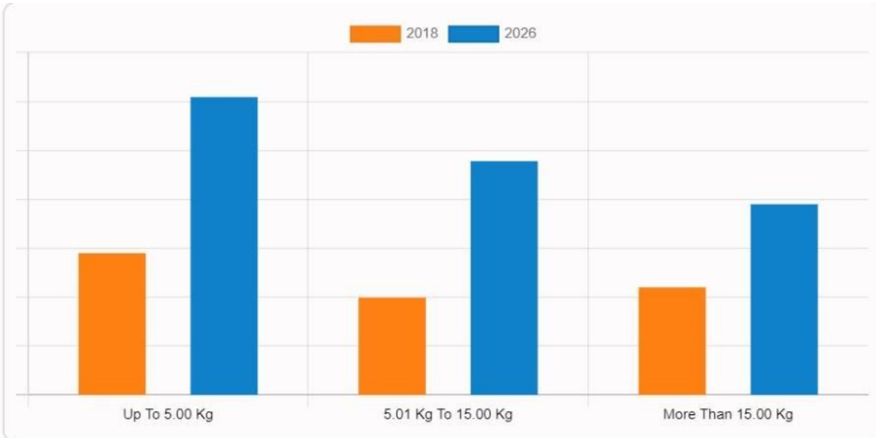
- Marketing: Highlight the environmental and efficiency benefits through digital marketing, trade shows, and industry publications.

- Sales Channels: Direct sales, partnerships with waste management companies, and collaborations with smart city projects.

- Pricing Strategy: Competitive pricing with options for leasing or financing to reduce upfront costs for customers.

SCARA Robot Market Outlook - 2026

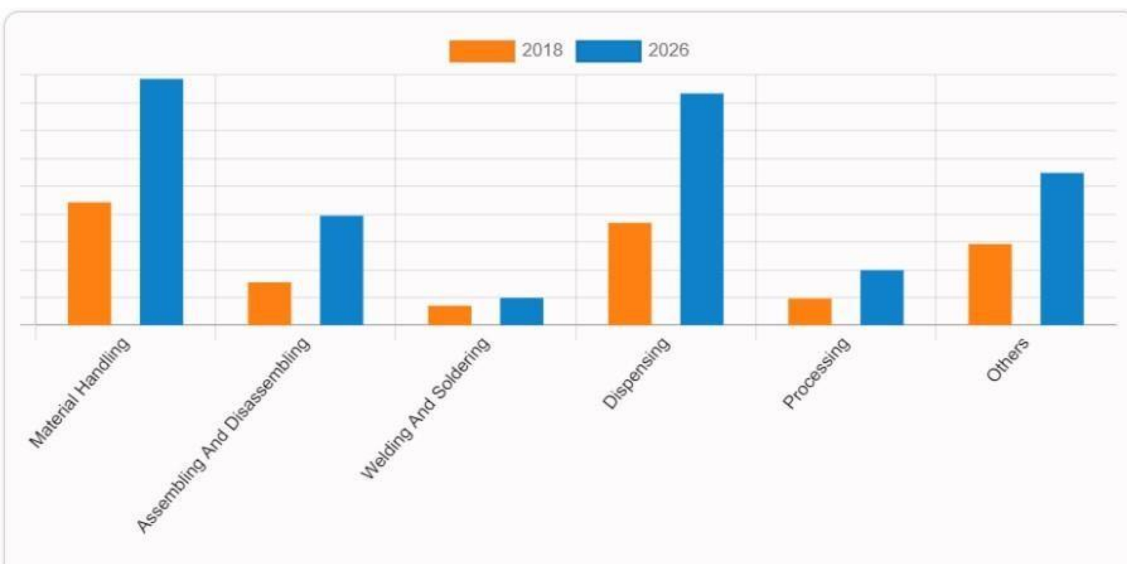
The global SCARA robot market size was valued at $7.10 billion in 2018, and is projected to reach $14.78 billion by 2026, registering a CAGR of 9.8% from 2019 to 2026. SCARA Stands for Selective Compliance Articulated Robot Arm, which is widely used in small robotic assembly applications



5.01 KG to 15.00 KG would exhibit the highest CAGR of 11.7% during 2019-2026.

Figure 1 SCARA Robot Market by Payload Capacity

The major factors that drive the global SCARA robot market include growing need for mass production with reduced operation cost, due to high demand for mass production in manufacturing industries to achieve low cost and high-quality production results. In addition, surge in adoption of industry 4.0, owing to various manufacturing industries focus to obtain safe, fast, and efficient production results, which boost the need for industrial application



Assembling and Disassembling would exhibit the highest CAGR of 12.6% during 2019-2026.

Figure 2 SCARA Robot Market by application

Based on region, the SCARA robot market analysis is done across North America, Europe, Asia-Pacific, and LAMEA. Europe dominated the SCARA robot market in terms of revenue in 2018, due to rise in demand for better biomedical and healthcare services by the aging European population, coupled with rising demand from end-user industries such as semiconductors manufacturing, polymers, metallurgy, and fiber optics.

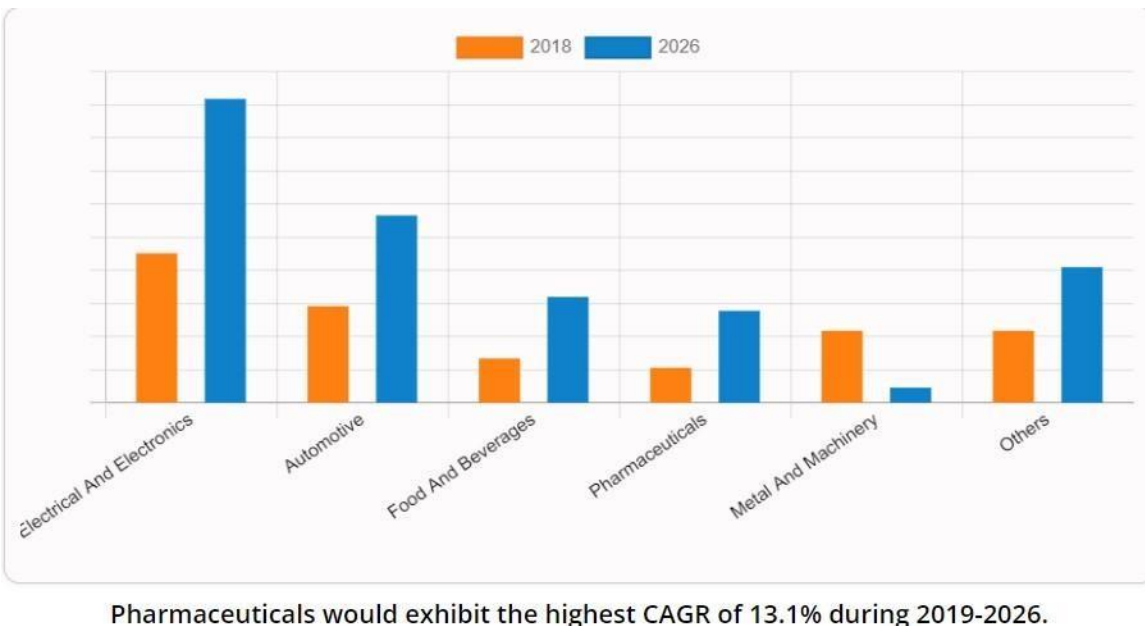


Figure 3 SCARA Robot Market By Industry Vertical.

Top Impacting Factors

The SCARA robot market trends such as growing need for mass production with reduced operation cost, surge in adoption of industry 4.0, and upsurge in demand for IoT-based smart solutions and automation in various industries for qualitative and reliable manufacturing, increase in application areas of collaborative robots, and rise in demand for automation in Asian countries such as China and Japan, are expected to significantly affect the growth of the global SCARA robot market. These factors are anticipated to either drive or hamper the market growth.

Aspects	Details
BY PAYLOAD CAPACITY	Up to 5.00 KG 5.01 KG to 15.00 KG More than 15.00 KG
BY APPLICATION	Material Handling Assembling and Disassembling Welding and Soldering Dispensing Processing Others
BY INDUSTRY VERTICAL	Electrical and electronics Automotive Food and Beverages Pharmaceuticals Metal and Machinery Others
By Region	North America (U.S, Canada, Mexico) Europe (UK, Italy, Germany, France, Rest of Europe) Asia-Pacific (China, Japan, India, South Korea, Rest of Asia-Pacific) LAMEA (Latin America, Middle East, Africa)

Key Market Players	ABB, Kawasaki Robotics (Kawasaki Heavy Industries, Ltd.), Mitsubishi Electric Corporation, KUKA AG, Fanuc Corporation, DENSO Corporation (DENSO Robotics), Yaskawa Electric Corporation, Seiko Epson Corporation, Stäubli International AG, OMRON Corporation

Table 1 SCARA Robot Market Report Highlights

1) Design of an Economical SCARA Robot for Industrial Applications

Authors report research on a Design of an Economical SCARA Robot for

Industrial Applications Along with choosing mechanical and electrical components, the design process also involved joint, link, and controller designs. Utilizing locally affordable components in Iran while keeping costs down posed a difficulty. With its 0.01 mm repeatability, 8.5 m/s maximum linear velocity in the xy plane, 0.5 second pick and place cycle time, and versatile control system, the FUM SCARA robot has amazing performance. A crucial trajectory is finally plotted within the workspace of the robot using a PID controller. The findings show reduced inaccuracy during the rapid trajectory. By needing a specialized bearing assembly, increasing the overall joint design, and raising the weight and inertia of the link, the use of planetary gearboxes instead of harmonic drives offered much additional obstacles. Additionally, using larger, more powerful motors was a byproduct of their choices. Additionally, to having industrial capacity, this robot also makes a fantastic research tool thanks to the usage of open architecture in its control system. The FUM SCARA, according to the creators, is one of the most affordable SCARA robots with distinct and competitive industrial requirements.[1]

2) Analysis and Implementation of Dual Pick and Place Operation in Smart Manufacturing

Authors report research on Analysis and Implementation of Dual Pick and

Place Operation in Smart Manufacturing Domain where a 4-axis dual pick-and-place operation is implemented in real time. Robot for handling components coming from a conveyor in an industrial setting. Dual picking and placement entail positioning for marking and inspection, followed by positioning in a bin in accordance with marking. For quick motion control, relevant sequence and motion information is transmitted via Ethernet and Ether CAT ports, together with sensors and reed switches. The MAT Lab environment has shown various robot postures during PNP operation. This system is appropriate for minimizing cycle time, improving efficiency, and increasing production.[2]

4. METHODOLOGY

4. 1. Needs and Capabilities

NEEDS

S1	**System Installation and integration**
ON 1.0	Maximum reach of the robot is 300mm.
ON 1.1	The dimension of conveyor should be 2000*330 (all dimensions in mm)
ON 1.2	The conveyor should be in the workspace of the robot
ON 1.3	The robot should be mounted on the tabletop
ON 1.4	User manual should be provided for the conveyor system and Robot
ON 1.5	The installation of the system should be easy
ON 1.6	Overall cost of the entire system should be less (within Rs.25000)
ON 1.7	Maintenance of the system should be easy
S2	**System Calibration**
ON 2.1	Calibration of the system should not take more time
ON 2.2	Initially the robot should be in default position
ON 2.3	The system should indicate that all the components are working and ready to pick
ON 2.4	If any error while in calibration, it should immediately alert the operator
S3	**Movement of Conveyor**
ON3.1	The conveyor system should receive command from the operator to start the system.
ON 3.2	The operator can give the command using push button/touchscreen
ON 3.3	Conveyor should run at a desired RPM
ON 3.4	If any error occurs while movement of the conveyor, it should immediately alert the operator
S4	**Robot starts**
ON 4.1	The power supply should be 12v

ON 4.2	The Robotic system should receive command from the operator to start the system
ON 4.3	The operator can give the command using push button/touchscreen
ON 4.4	The robot starts with the help of a push button
S6	**Pick**
ON 6.1	The end effector should pick the trash safely from the conveyor
ON 6.2	The gripper should be soft, made of flexible material
ON 6.3	The gripping force should be controlled precisely
S7	**Move the Arm carefully**
ON 7.1	The robot arm should safely move near the allocated bin
S8	**Place**
ON 8.1	The robot should move the arm near the allocated bin
ON 8.2	The end effector should place the trash safely
ON 8.3	The trash should be placed in respective bins
S9	**Shut down**
ON 9.1	The system should turn off when push button is pressed
ON 9.2	The entire system should shut when we turn off the power supply
ON 9.3	The conveyor and the camera also shut when the power button is pressed
ON 9.4	The robot arm should come to its default position
S10	**Emergency stop**
ON 10.1	The entire system should shut when we press emergency button
ON 10.2	The power supply should be cut to the system
S11	**Precaution**
ON 11.1	During installation, specific high-level sensors should be implemented to prevent collisions with the environment,

Table 2 Needs of Scara Robot Capabilities

	Capability	Description

C1	**Autonomous operations**	The robot should be able to process the operations automatically
C1.1	**Pick Trash**	The robot can pick the trash
C1.2	**Handle with care**	The robot can move its arm by holding the trash without dropping it in the middle
C1.3	**Place trash**	The robot can place the trash into the respective bins
C1.4	**Manage the flow**	The robot keeps a note about the trash and intimates the operator when the trash are empty.
C2	**Safe**	Safety is the key aspect in the robot. The robot should not cause any harm to the system and the product. Safety is the complex capability in a robot that requires both realization of certain functionalities and quality attributes.
C2.1	**Pick trash safely**	The robot picks the trash safely avoiding damage to the trash and avoid collision with either system, trash or operator
C2.2	**Handle the trash**	The robot should hold the trash carefully without losing the grip or colliding with obstacles
C2.3	**Rotate the arm carefully**	The robot arm rotates at certain angles depending upon the bins in which the cocoons need to be dropped
C2.4	**Place cocoon safely**	The robot places the trash in respective bins
C3	**High availability**	The robot shall be available for at least 95% of the time. Increased availability is a complex capability which makes way to various quality attributes. This capability will map to reliability requirements for components of robotic system.
C4	**Contingency planning**	Contingency planning for a robot involves anticipating potential failures or malfunctions that may occur during its operation, and developing strategies to minimize their impact or prevent them from happening altogether.
C5	**Resilience Analysis**	Resilience analysis of a robot involves assessing its ability to maintain its functionality and performance despite various internal and external disturbances or disruptions.

C6	**Operator interface**	An operator interface for a robot is a critical component that allows a human operator to interact with and control the robot during its operation

Table 3 Capabilities of Scara Robot

4.2 Operational Scenarios

	Operational scenarios	
S1	**System Installation and integration**	The operator installs the pick and place robot on the surface. The operator adds a conveyor system and a camera alongside the pick and place robot and connects the robot through operator interface.
S2	**System Calibration**	The system is checked and calibrated to ensure all subsystems are functioning properly and to achieve accurate control during pick-and-place tasks, after configuration.
S4	**Robot Starts**	The operator turns on the robot and subsystems. The robot and subsystem include robot and camera. The robot calibrates all its joints and links.
S5	**Capture Image**	The camera captures images of the cocoons, which are then analyzed using image processing algorithms to detect abnormalities and trigger signals to the controller.
S6	**Pick**	Using its end effector, the robot picks up trash from the conveyor.
S7	**Move arm carefully**	The robot moves its arm with precision and care to avoid damaging the environment, objects, and the operator, while ensuring that the trash are not dropped or damaged.
S8	**Place**	After picking up the defected trash it accurately places it at the desired location by adjusting its arm and the end effector accordingly

S9	**Shut Down**	By using the user interface, the operator shuts down the robot, resulting in the storage of trash status in memory and movement of the robot arm to its default position.
S10	**Emergency Stop**	If the robot malfunctions, the emergency stop button can be used to halt its operation
S11	**Precaution**	During installation, specific high-level sensors should be implemented to prevent collisions with the environment, and necessary precautionary measures should be taken.

Table 4 Operational Scenarios

4.3 Capabilities and High-Level Functional Requirements

Functions		**Description**
F1	**User Inputs**	The User inputs starts communication with the system. This function Provides Information the system.
F2	**Calibration**	Calibration is an important process as it ensures that the robot is able to accurately and reliably perform its intended tasks.
F5	**User Interface**	The User handles the communication with the system via suitable devices. This function helps the operator manage the work of the entire system and track the status of the system.
F6	**Pick Product**	The robot is directed to pick the trash from the conveyor system. The system moves its arm to a desired location and picks the cocoons from that position.
F7	**Place Product**	This function helps the robot is directed to place the trash in the bin
F8	**Hold Operations**	This function Notifies the operator to hold the current operation until the product is detected.
F9	**Stop Operations**	This can be an important function in certain situations where the robot needs to pause or stop its operation for safety reasons, to adjust or reposition its end-effector, or to wait for further instructions from the control system.

F10	**Reset Position**	The "reset operation" typically refers to the process of returning the robot to a known or default state after an error or malfunction has occurred. The reset operation can be an important function for restoring the robot to normal operation and avoiding damage or injury.

Table 5 High Level Function Requirement

4.4 Functional Architecture and System Requirements

F1 User Inputs.

F1.1 When <input ‘Power On ’ is received >the function <F1.1> shall generate <output ‘System is on’ >.

F1.1 When <input ‘Power Off ’ is received >the function <F1.1> shall generate <output ‘System is Off’ >.

F2 Calibration.

F2.1 When <input ‘System is on ’ is received >the function <F2.1> shall generate <output ‘Calibration is Successful ’ >.

F2.2 When <input ‘Calibration is Successful’ is received >the function <F2.2> shall generate <output ‘ Home position’ >.

F2.3 When <input ‘Reset ’ is received >the function <F2.3> shall generate <output ‘Calibration is Successful AND Home position ’ >.

F5 User Interface

F5.1 When <input ‘Power Supply’ is received >the function <F5.1> shall generate <output ‘User Credentials’ >.

F5.2 When <input ‘User Credentials’ is received >the function <F5.1> shall generate <output ‘Logged In’ >.

F5.3 When <input ‘Logged In’ is received >the function <F5.1> shall generate <output ‘Main menu’ >.

F5.4 When <input ‘Logged In’ is received >the function <F5.1> shall generate <output ‘Dashboard’ >.

F5.5 When <input ‘Dashboard’ is received >the function <F5.1> shall generate <output ‘Status of the system’ >.

F5.6 When <input ‘Stop Operation’ is received >the function <F5.1> shall generate <output ‘Current Operation Stops’ >.

F5.7 When <input ‘Hold Operation’ is received >the function <F5.1> shall generate <output ‘Notify the user’ >.

F5.8 When <input ‘Reset’ is received >the function <F5.1> shall generate <output ‘System is at Home position’ >.

F5.9 When <input ‘Hold Operation’ is received >the function <F5.1> shall generate <output ‘Notify the user’ >.

F6 Pick Product

F6.1 When <input: ‘Fault Product should be Picked’>, The function<F6.1>Shall generate <output: ‘Coordinates>.

F6.2 When <input: ‘Product Coordinates’>, The function<F6.2>Shall generate <output: ‘Product Coordinates are imported>

F6.3 When <input: ‘Product Coordinates are imported’>, The function<F6.3>Shall generate <output: ‘Current Coordinates of the end effector>

F6.4 When <input: ‘Product Coordinates are imported AND Current Coordinates of the end effector’>, The function<F6.4>Shall generate <output: ‘Ready to Pick the Product’>

F6.5 When <input: ‘Ready to Pick the Product’>, The function<F6.5>Shall generate <output: ‘Product is picked ’>

F6.6 When <input: ‘Product is picked’>, The function<F6.6>Shall generate <output: ‘Product is ready to be placed’>

F7 Place Product

F7.1 When <input: ‘Import Coordinates of the Bin ’>, The function<F7.1>Shall generate <output: ‘ Coordinates of bin is Imported ’>

F7.2 When <input: ‘Coordinates of bin is Imported AND Product is ready to be placed ’>, The function<F7.2>Shall generate <output: ‘ Gripper Releases the Product ’>

F7.3 When <input: ‘Gripper Releases the Product ’>, The function<F7.3>Shall generate <output: ‘ Product is Released ’>.

F8 Hold Operations

F8.1 When <input ‘Product is Not Present on the conveyer ’ is received >the function <F8.1> shall generate <output ‘Return To Pick’ >.

F9 Stop Operations

F9.1 When <input 'Emergency Stop' is received >the function <F9.1> shall generate <output 'Stop Operation' >.

F9.1 When <input 'Stop Operation' is received >the function <F9.2> shall generate <output ' Notify the user' >.

F10 Reset Position

F10.1 When <input 'Product placed' is received >the function <F10.1> shall generate <output 'home position' >.

F10.2 When <input 'Logged out'' is received >the function <F10.2> shall generate <output 'home position' >.

F10.3 When <input 'home position'' is received >the function <F10.3> shall generate <output 'System is Ready' >.

4.6 Design – Mechanical

SCARA robots consist of several mechanical components that enable their operation and movement. The key components of SCARA robot are Base, Arm ,Joints , End effector, Actuators, belts and pulleys

Procedure for designing and printing of robotic Base, Arm, Pulleys and End effector

1) **Defining the requirements**: Firstly, we Determine the specific needs of our SCARA robot link. Consider factors such as payload capacity, reach, accuracy, and speed. These requirements will guide the design process.
2) **Sketch the initial design**: By sketching the basic structure of the SCARA robot link. This will include the main arm, and end-effector. Consider the overall shape, dimensions, and the joints required for movement.
3) **Select material**: By Considering the mechanical properties, such as strength and rigidity, as well as the printing capabilities of your 3D printer. We have used ABS for 3D printing
4) **CAD modeling**: We have used Solid works software for designing the parts.
5) **Design for assembly**: By considering how the different parts of the SCARA robot link will be assembled. Design features such as mounting holes, slots, and tabs to enable easy and secure attachment of the components.
6) **Optimize for strength and weight**: We have used engineering principles to optimize the design for structural strength while minimizing weight.

7) **Check for interference and clearance**: We have Verify that the different parts of the SCARA robot link do not interfere with each other during movement. Ensure there is sufficient clearance for joints to rotate freely and for the desired range of motion.
8) **Generate 3D printable files**: Once the design is finalized, export the CAD model to a format compatible with 3D printer (such as STL)..
9) **Printing:** We have Loaded the 3D printable files into your 3D printer and initiate the printing process.
10) **Assembly:** Firstly we started assembling base followed by Arm , Links , pulley , belts , actuators , joint connections , end-effector and connected the electrical wires
11) **Testing**: Once the assembly is complete, we conduct testing of the SCARA robot. Verify the movement and functionality of each joint and ensure that all components are properly connected and working as intended.

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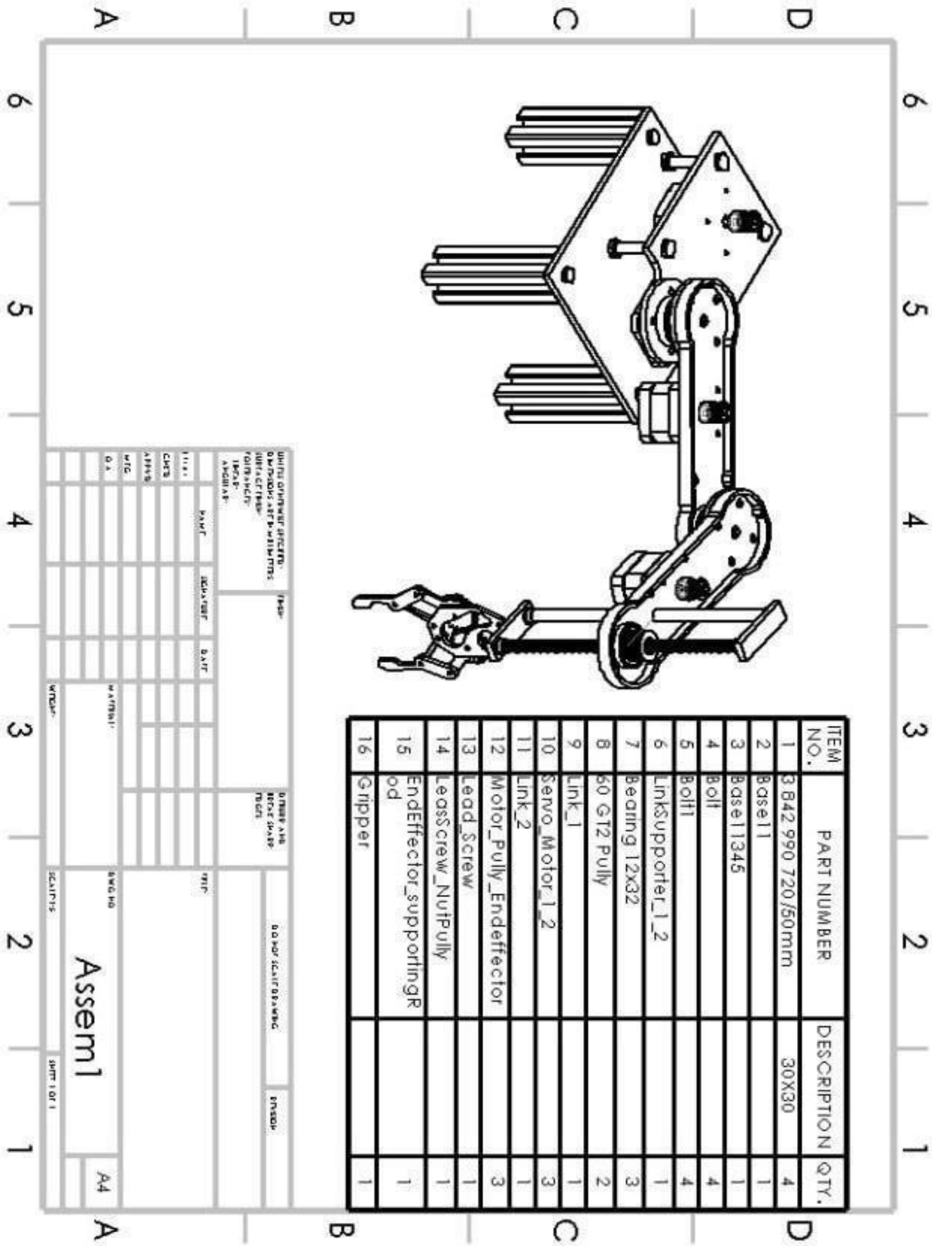
15) **Design for assembly**: By considering how the different parts of the SCARA robot link will be assembled. Design features such as mounting holes, slots, and tabs to enable easy and secure attachment of the components.
16) **Optimize for strength and weight**: We have used engineering principles to optimize the design for structural strength while minimizing weight.
17) **Check for interference and clearance**: We have Verify that the different parts of the SCARA robot link do not interfere with each other during movement. Ensure there is sufficient clearance for joints to rotate freely and for the desired range of motion.
18) **Generate 3D printable files**: Once the design is finalized, export the CAD model to a format compatible with 3D printer (such as STL)..
19) **Printing:** We have Loaded the 3D printable files into your 3D printer and initiate the printing process.
20) **Assembly:** Firstly we started assembling base followed by Arm, Links , pulley , belts , actuators , joint connections , end-effector and connected the electrical wires

21) **Testing**: Once the assembly is complete, we conduct testing of the SCARA robot. Verify the movement and functionality of each joint and ensure that all components are properly connected and working as intended.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	3 842 990 720/50mm	30X30	4
2	Base1		1
3	Base11345		1
4	Bolt		4
5	Bolt1		4
6	LinkSupporter_1_2		1
7	Bearing 12x32		3
8	60 GT2 Pully		2
9	Link_1		1
10	Servo_Motor_1_2		3
11	Link_2		1
12	Motor_Pully_Endeffector		3
13	Lead_Screw		1
14	LeasScrew_NutPully		1
15	EndEffector_supportingRod		1
16	Gripper		1

Figure 5 Bill Of Materials

4.8 Design – Electrical & Electronics

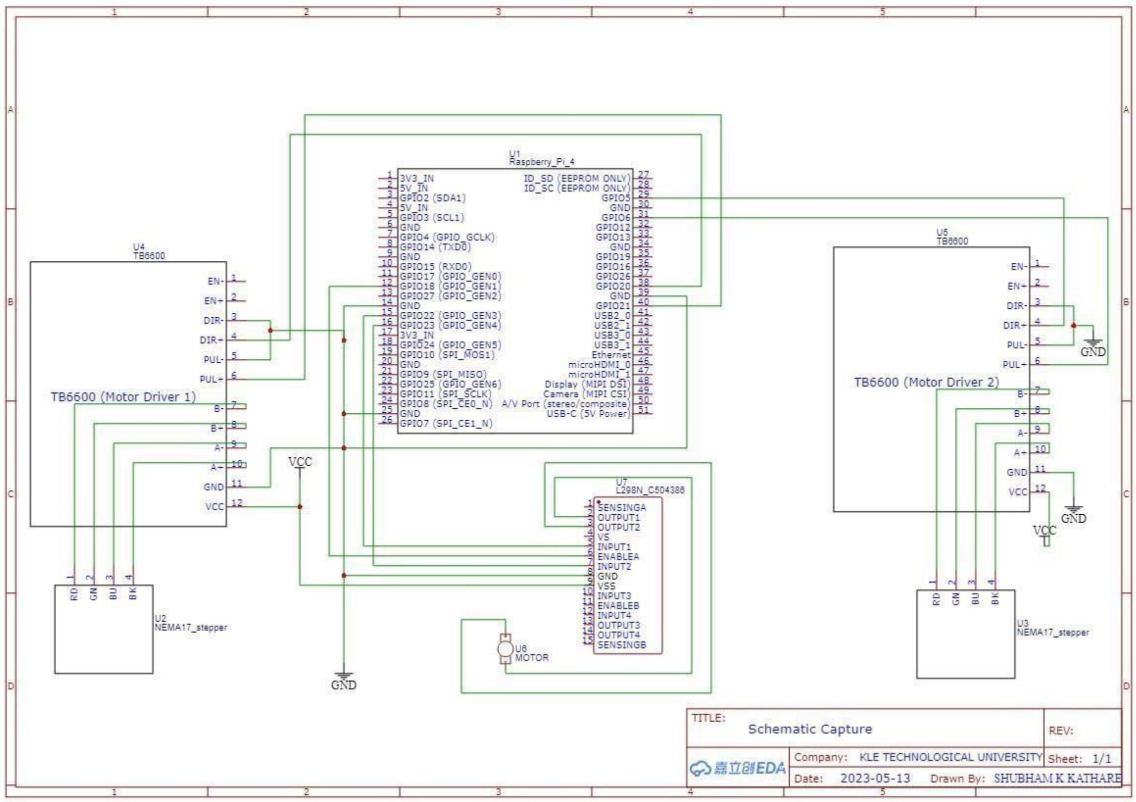


Figure 6 Electrical Circuit

1)Identify System Requirements:

We needed two stepper motors with 0.4Ncm. And two stepper motor drivers to control the selected motors one for ach link, and a high RPM DC motor to Actuate the lead screw which is connected to the end effector. To control the Stepper Motors via Drivers we have used a processor.

2)Component Selection:

We selected Raspberry Pi as the processor. And we have used 2 Nema17 motors to actuate Two links and to control them we have used Two TB6600 micro stepper driver, one for each motor and to actuate the lead screw we have used DC motor with 300Rpm and for the power supply we have used 12Volts Adapter, to connect them with each other we have used jumper wires.

3) Motor Control:

We have used TB6600 to control the NEMA17.

4) Microcontroller and Communication:

Raspberry Pi as the controller which has the 40 Gpio pins and we have connected the driver Direction and pulse pin to the Pi and also the DC motor driver pins are connected to the pi.

5) Power Supply Design:

We connect the Raspberry Pi to 3.3v supply from a power bank and to power the driver and motors we have used a 12 volts DC Adapter with 1.5 Amps current output.

Where the rated current of the Nema17 motor is 1.7 amps, but we operate the motor on 1 Amps Max. To reduce the current we set the motor drivers to range between 0.7 to 1.0 Amps.

Motor Torque Calculation

Link 2: Motor weight = 250gms

Mass of link 2 = 41.90gms

Mass of lead screw = 31.65gms

Mass of end effector = 30gms

Mass of product = 5gms

Length of link2 = 150mm

Link 1: Mass of motor = 250gms

Mass of link1 = 41.90gms

Length of link1 = 150gms Total

weight of link2 = 5.378kg Link

2:

=250+41.90+31.65+30+5

=358.55gms

=0.35855kg =0.35855kg

* 15cm

=5.378kg/cm Link1:

=250+41.90

=291.9

=0.2919*15kg/cm

=4.3785kg/cm

Total Torque of link1 and link2

=4.3785+5.378

=9.7565kg/cm

Total workspace of the over robot

=300mm length.

4.9 Design - Software

Software Tools used in 3-DOF SCARA Robot

1) Solidworks

SolidWorks can be used in several ways for designing and simulating the cocoon picking SCARA robot. Here are some specific use cases of SolidWorks in the context of cocoon picking:

1) Modeling and Design

2)Assembly and Kinematics

3)Motion Simulation and Analysis

4)Visualization and Documentation

By utilizing SolidWorks, engineers can design, simulate, and validate the cocoon picking SCARA robot, ensuring its mechanical integrity, range of motion, and functionality. The software facilitates the visualization, analysis, and documentation of the robot's design, helping to optimize the picking process and ensure efficient operation.

3) Easy EDA

EasyEDA is a web-based electronics design tool that focuses on schematic capture and PCB layout. While EasyEDA may not be directly applicable to the mechanical aspects of the cocoon picking SCARA robot, it can be utilized for designing and prototyping the electronic control system of the robot.While EasyEDA primarily focuses on electronics design, it can still be a valuable tool for designing and prototyping the electronic control system of the cocoon picking SCARA robot. The software's schematic design, component selection, simulation, PCB layout, and collaboration features provide an integrated platform for creating and iterating the electronic control system design.

4) Thonny Python IDE

Thonny Python IDE (Integrated Development Environment) can be used for developing the software components and algorithms for the cocoon picking SCARA robot. Thonny provides a user-friendly interface and a range of features that facilitate the development and testing of Python-based software. Here's how Thonny Python can be utilized for the cocoon picking SCARA robot Thonny Python IDE provides a user-friendly and intuitive environment for developing and testing the software components of the cocoon picking SCARA robot. Its features for code editing, debugging, integration with libraries, and data visualization contribute to the efficient development and deployment of the Python-based software for the robot's control and cocoon picking operations. **4.10 Design – Architectural Design**

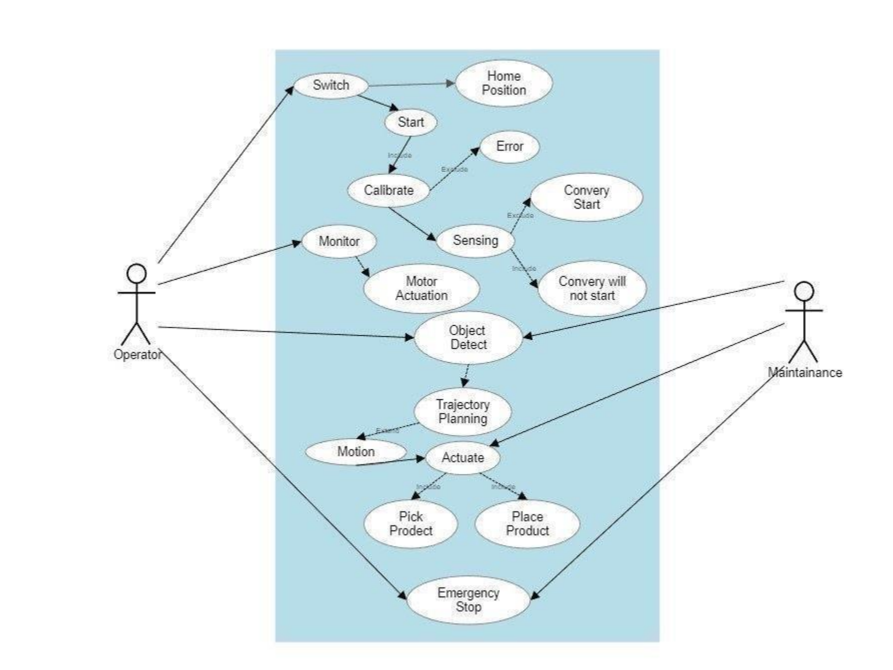


Figure 7 Use Case Diagram

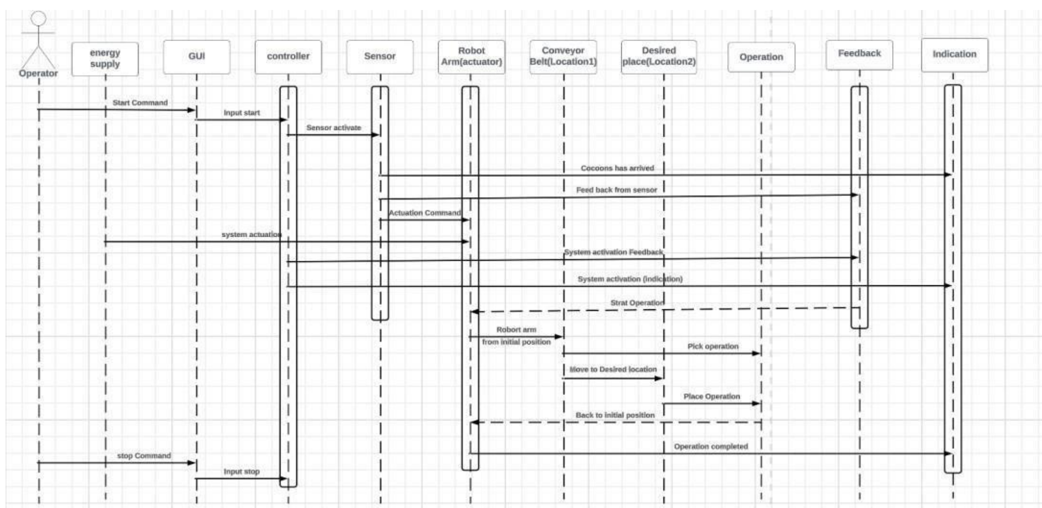


Figure 8 Sequence Diagram IMPLEMENTATION AND VALIDATION

Implementation and validation of a SCARA robot involves the practical deployment of the robot system and verifying its performance against predefined criteria. Here's a procedure for implementing and validating a SCARA robot.

1) System Setup:

a. Prepare the workspace: Clear the workspace and set up any necessary fixtures or workstations for the trash picking task.

b. Install the SCARA robot: Set up the SCARA robot in the designated area, ensuring it has proper power supply and connectivity to the control system.

2) Programming and Control:

a. Robot programming: robot's programming to perform the trash picking task. This includes defining the motion trajectories, control logic.

b. Implement safety measures: Incorporate appropriate safety measures, such as emergency stop buttons, protective barriers, or motion monitoring systems, to ensure safe operation of the robot.

3) Testing and Validation:

a. Calibration: Calibrate robot's motion parameters to ensure accurate trash position and precise robot movement.

b. Performance evaluation: we define performance metrics for the trash picking task, such as success rate, cycle time, and accuracy. We conduct initial tests to assess the robot's performance against these metrics.

c. Iterative refinement: Analyze the test results and identify any issues or areas for improvement. Iterate on the programming, control, or hardware setup to enhance the robot's performance and efficiency.

d. Robustness testing: Conduct rigorous testing under different conditions, including variations in environmental factors. Evaluate the robot's ability to handle these variations and make necessary adjustments if required.

e. Validation criteria: Establish predefined validation criteria for the robot's performance. This may include minimum success rates, cycle times, or picking accuracy that the robot must meet for satisfactory operation.

4) Optimization and Fine-tuning:

a. Optimization: Optimize the robot's programming and control parameters to improve speed, accuracy, or efficiency. This may involve fine-tuning motion trajectories, gripping mechanisms.

b. Iterative testing: Continuously test and evaluate the robot's performance after each optimization iteration. Compare the results against the predefined validation criteria to ensure the robot meets the desired performance levels.

c. Documentation: Maintain thorough documentation of the implementation, modifications, and optimization steps performed, including the programming code, calibration parameters, and test results.

5) Deployment:

a. Production environment: Once the cocoon picking SCARA robot has been successfully implemented and validated, deploy it in the intended production environment.

b. Operator training: Provide training to the operators who will be working with the robot, ensuring they understand its operation, safety procedures, and maintenance requirements.

c. Continuous monitoring: Regularly monitor the robot's performance in the production environment, addressing any issues that arise and making necessary adjustments to maintain optimal performance.

CONCLUSIONS AND FUTURE WORK

6. 1. **Conclusions**

In conclusion, the implementation of a cocoon picking system using a SCARA (Selective Compliance Assembly Robot Arm) robot offers significant benefits in terms of accuracy, efficiency, and productivity. Through this appendix, we have explored the various aspects involved in designing and operating such a system, addressing the challenges associated with delicate trash handling.

By integrating a SCARA robot into the trash picking process, the system achieves precise and repeatable movements, ensuring minimal damage to the fragile cocoons. The use of a vision system allows for accurate detection and localization of the trash, enabling the robot to perform targeted picking with high precision. Automating the picking process not only reduces labor costs but also enhances productivity, as the robot can work continuously without experiencing fatigue.

Through careful consideration and design, the appendix has provided guidance on the selection and integration of the appropriate hardware and software components. The programming of the SCARA robot, including the kinematic model and inverse kinematics, ensures accurate and coordinated movements required for successful trash picking. Error handling and recovery mechanisms have been discussed to ensure the system's robustness and reliability.

Testing and optimization play crucial roles in fine-tuning the trash picking system. By evaluating the system's performance, identifying potential bottlenecks, and optimizing parameters, the efficiency and accuracy of the system can be further enhanced. Error analysis and troubleshooting techniques have been provided to address common issues that may arise during operation, minimizing downtime and ensuring smooth performance.

Safety considerations are of paramount importance when deploying a SCARA robot in cocoon picking. By implementing safety precautions for human operators working alongside the robot, potential risks can be mitigated. Additionally, regular maintenance and failure detection measures ensure the system's longevity and minimize disruptions to the picking process.

The successful implementation of a trash picking system using a SCARA robot offers numerous advantages to industries involved in trash harvesting and processing. The automated system reduces labor costs, improves productivity, and enhances the overall quality control of the process. Moreover, the system minimizes the risk of damage or contamination to the delicate cocoons, ensuring their integrity and value.

As with any technological solution, there are opportunities for further enhancements and future advancements in the field of trash picking with SCARA robots. Research and development can focus on improving the vision system's accuracy and speed, exploring advanced gripper designs for even gentler handling, and implementing artificial intelligence techniques to optimize the picking process.

In conclusion, this appendix serves as a valuable resource for understanding the implementation of a cocoon picking system using a SCARA robot. By following the guidelines and considerations presented herein, industries can benefit from an automated and efficient solution that revolutionizes the cocoon picking process, resulting in improved productivity, quality, and overall operational success.

6. 2. **Future Work**

The implementation of a cocoon picking system using a SCARA (Selective Compliance Assembly Robot Arm) robot provides a solid foundation for improving the efficiency and accuracy of the cocoon picking process. However, there are several avenues for future work and enhancements to further optimize the system and explore new possibilities. This section highlights potential areas for future development:

1. Advanced Vision System: Enhancing the vision system used for cocoon detection and localization can lead to improved accuracy and speed. Research and development efforts can focus on utilizing advanced image processing algorithms, machine learning techniques, and 3D vision technologies to enhance the system's capability to identify and locate cocoons in complex environments.
2. Gripper Design and Sensing: Further advancements in gripper design can contribute to more delicate and precise handling of the fragile trash. Exploring innovative gripper designs, such as soft or compliant grippers, can provide improved gripping capabilities while minimizing the risk of damage. Integration of force/tactile sensors in the gripper can provide feedback on the gripping force, enabling adaptive grasping strategies.
3. Intelligent Path Planning: Implementing intelligent path planning algorithms can optimize the robot's movement trajectory, minimizing the time required to pick cocoons and reducing unnecessary movements. Path planning algorithms that consider the spatial arrangement of the trash and the workspace constraints can further improve the system's efficiency and overall performance.
4. Autonomous System: Moving towards a fully autonomous system where the robot can autonomously navigate the workspace, detect and locate trash, and perform picking tasks without human intervention is an exciting area of future work. Integration of advanced sensing technologies, such as depth cameras or LiDAR, along with intelligent decision-making algorithms, can enable the robot to adapt to dynamic environments and handle complex scenarios.
5. Collaborative Robot Systems: Investigating the potential of collaborative robot systems, where the SCARA robot can work alongside human operators in a cooperative and safe manner, can further enhance the flexibility and productivity of trash picking processes. Implementing safety features and algorithms for human- robot interaction can open up new possibilities for efficient and ergonomic trash picking workflows.
6. Optimization and System Integration: Continuous optimization of the trash picking system by fine-tuning parameters, refining algorithms, and integrating real-time monitoring and control systems can contribute to improved overall performance and adaptability. Integrating the cocoon picking system with other stages of the waste processing workflow, such as sorting or packaging, can create a comprehensive and highly efficient automated process.
7. Scalability and Adaptability: Developing a trash picking system that can easily adapt to different types of trash, sizes, and variations is crucial for widespread adoption.

Future work can focus on designing modular systems that can be easily configured and reconfigured to accommodate different trash types and production requirements.

8. In conclusion, future work in the field of trash picking with SCARA robots holds immense potential for further optimization and advancement. By exploring advanced vision systems, gripper designs, intelligent algorithms, and collaborative robot systems, the efficiency, accuracy, and adaptability of the cocoon picking process can be significantly improved. These advancements will contribute to increased productivity, reduced labor costs, and enhanced quality control in industries relying on trash harvesting and processing.

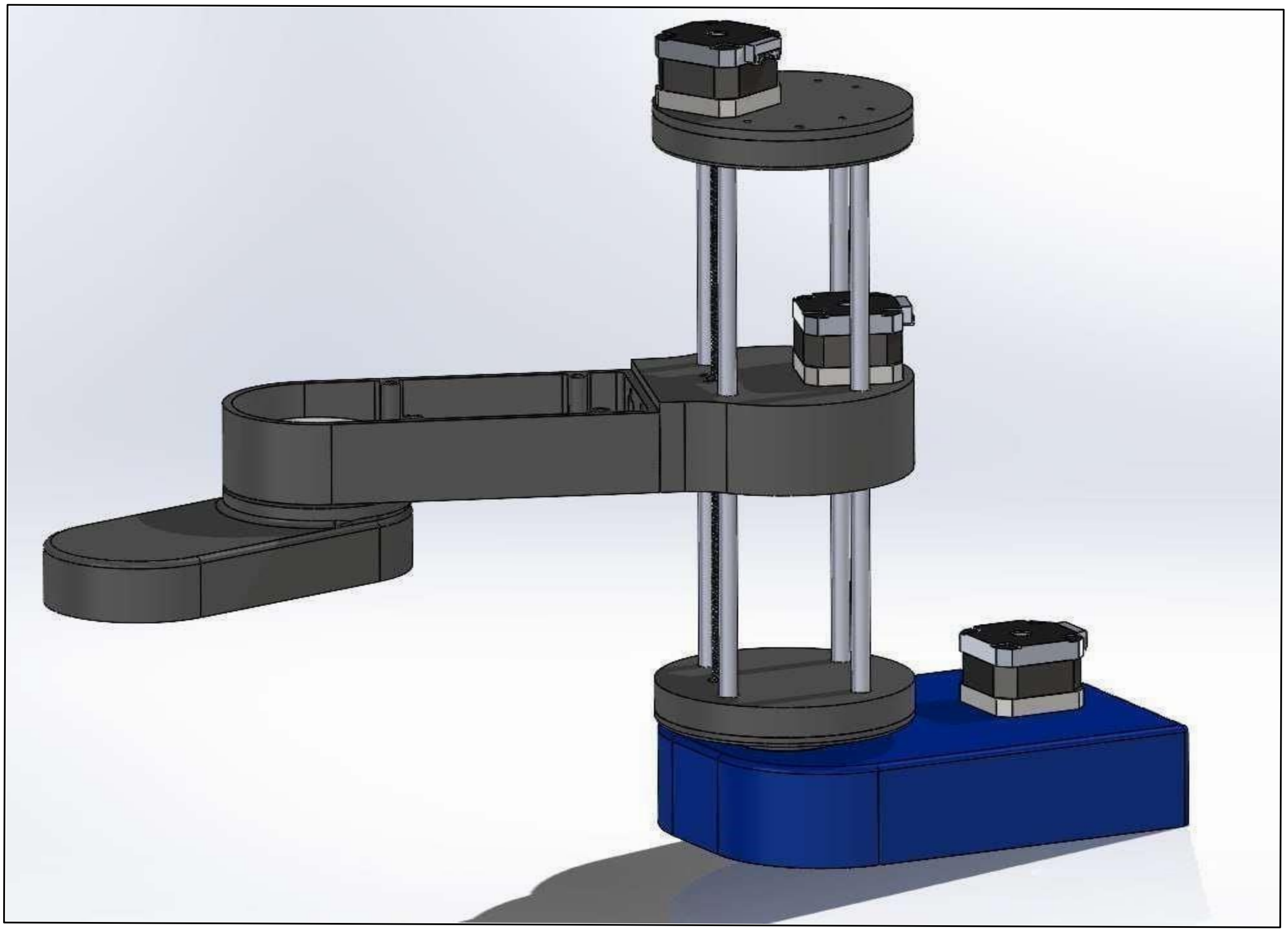
APPENDIX A

CODE

```
from time import sleep import RPi.GPIO
as GPIO

GPIO.setwarnings(False)
DIR_1 = 5
STEP_1 = 6

DIR_2 = 20
STEP_2 = 21

CW = 1
CCW = 0 servo_pin = 4 # GPIO pin number where the servo is
connected

GPIO.setmode(GPIO.BCM)

GPIO.setup(DIR_1, GPIO.OUT)

GPIO.setup(STEP_1, GPIO.OUT)

GPIO.setup(DIR_2, GPIO.OUT)
GPIO.setup(STEP_2, GPIO.OUT)

GPIO.setup(servo_pin, GPIO.OUT)

step_count_1 = 111 step_count_2
= 111  delay
= 0.010

pwm = GPIO.PWM(servo_pin, 50) # Create a PWM instance with a frequency of 50Hz
pwm.start(0) # Start PWM with a duty cycle of 0 (neutral position)


def set_angle(angle): duty_cycle = 2 + (angle / 18) # Map angle (0-180 degrees) to a duty cycle range
(2- 12)
```

```
        pwm.ChangeDutyCycle(duty_cycle)
        sleep(0.9)

    while(True):
        i = 0 j
        = 0 x
        = 0 k
        = 0 G
        = 0

        while(i<step_count_1):

            GPIO.output(DIR_1, GPIO.HIGH)

            GPIO.output(STEP_1,
            GPIO.HIGH) sleep(delay)
            GPIO.output(STEP_1, GPIO.LOW)
            sleep(delay)
            i= i+1


        while(x<step_count_1):
            GPIO.output(DIR_2, GPIO.HIGH)

            GPIO.output(STEP_2, GPIO.HIGH)
            sleep(delay)
            GPIO.output(STEP_2,
            GPIO.LOW) sleep(delay) x= x+1


         # Give the servo time to reach the desired position
        set_angle(0)  # Move the servo to 0 degrees
        sleep(1)        # Wait for 1 second set_angle(50)
                # Move the servo to 90 degrees
# Wait for 1 second  # Wait for 1 second   while(j<step_count_1):

            GPIO.output(DIR_1,     GPIO.LOW)
            GPIO.output(STEP_1, GPIO.HIGH)
            sleep(delay)


            GPIO.output(STEP_1,
```

```
GPIO.LOW) sleep(delay) j= j+1

while(k<step_count_1):

        GPIO.output(DIR_2,     GPIO.LOW)
        GPIO.output(STEP_2, GPIO.HIGH)
        sleep(delay)

        GPIO.output(STEP_2,
        GPIO.LOW) sleep(delay) k= k+1

    set_angle(0)  # Move the servo to 0 degrees
    sleep(1)        # Wait for 1 second

pwm.stop()          # Stop PWM
GPIO.cleanup()  # Reset GPIO pins
```



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