Robotic Arm For Pick And Place Applications

210618N - U.H.A.I Srimal
Department of Electrical Engineering
University of Moratuwa

210630T - Thanalakshan S
Department of Electrical Engineering
University of Moratuwa

210631X - Tharaka D.G
Department of Electrical Engineering
University of Moratuwa

***Abstract*—The main objective of this project will be to create a robotic arm intended for use in pick-up and placing functions through Solidworks and Matlab. This project seeks to design an advanced robot able to lift objects from a certain designated space and place them where desired, as per given commands.**

***Index Terms*—Robotic Arm, Pick, and Place**

I. INTRODUCTION

A robotic arm is a versatile and programmable engineering design that functions as a human arm. It can perform precise and repetitive tasks and risky tasks at the industrial level. Development and application of robotic arms have increased over the past few years.

The process of development of pick and place robotics goes back to the middle of the 20th century when the first industrial robots for the simplest materials manipulation appeared. Pick and place robots are being used in manufacturing systems over time as a result of improvements in electronics, control system technology, and AI.

Robotics encompasses control and computer systems, sensory feedback, utilization of robots, design and production, robots application.

Many engineering facets are required in the development of a robotic arm like mechanical engineering, electrical engineering, and electronic engineering. Such factors are important in building a robotic arm that satisfies specified performance conditions, safety levels, and dependability demands.

Categories of robots based on their applications include:

Industrial Robots: Robots find extensive application in various industrial settings, particularly in tasks requiring repetitive actions, precision, endurance, speed, and reliability. Many tasks that were traditionally performed by humans are now efficiently carried out by industrial robots. The industrial robots are versatile and serve different roles in transporting materials through a machine, addition operations like assembling, welding, and even gluing and painting, or taking out materials using subtractive manufacturing processes like milling, cutting, and grinding. Industrial robot controller, has good I/O communications and often serves as a controller of an individual cell in the scheme for flexibly manufacturing cell or system.[1]

Fig. 1. Industrial Robots

Mobile Robots (AGV - Automated Guided Vehicles): Also referred to as AGVs, mobile robots play a crucial role in transporting materials across large areas, such as hospitals, container ports, and warehouses. They navigate using methods like floor-embedded wires, markers, lasers, or vision systems to sense and adapt to their operating environment. AGVs perform three key operations and exhibit specific features: they convey materials, replacing hand labour, while also serving as mobile workbenches. The application of AGVs brings about four advantages: Reduction in trolley related accidents during the loading and offloading process; less labor required for goods handling; increased traceability of goods minimizing losses; environmental protection and power efficiency.[2]

Agriculture Robots: Despite sounding like a concept from futuristic science fiction, robots are being experimented with for agricultural purposes. These robots are designed to perform tasks like planting seeds, plowing fields, and harvesting crops. For instance, there are prototypes capable of picking apples in orchards. In addition, the challenges of shortage of workers are added to this mix due to the increasing trend for larger farm sizes, a decrease of farmers, and a growing impact on the environment in food production. Therefore, they need to adopt other productive and improved agricultural methods for increased production. Implementation of intelligent machines in traditional farming methods will go a long way in revolutionizing farmer's manual practice of cultivating and the management of cropping systems.[3]

Fig. 2. Agricultural Robot

Telerobots: Deployed in hazardous or inaccessible environments, telerobots are remotely operated by a human operator situated at a safe distance. This method allows for control in environments where human presence might be risky. Telerobots have applications in various areas, including handling hazardous materials in nuclear power plants.

Fig. 3. Tele Robot

Service Robots: This category encompasses robots used outside industrial settings and can be further divided into two main types. The first type includes robots designed for professional tasks, while the second type consists of robots intended for personal use. Service robots play diverse roles in assisting and enhancing tasks in both professional and domestic environments. On the other hand, service robots provide various benefits that can facilitate operations, and promote quality services with lower operational costs. The robots allow businesses to collect information, process that data on live basis and respond to changing market trends in a timely manner. These include intelligent robotic wheelchairs, surveillance drones, educational robots, therapy robots, entertainment robots, and self-driving cars.[4]

Fig. 4. Service Robot

II. Literature Review

The field of pick and place robot arms has witnessed significant advancements, playing a pivotal role in the automation of diverse industrial processes. These robotic systems are integral to applications ranging from manufacturing and assembly to logistics and order fulfillment. This highlights the evolving landscape of pick and place robotics, with a focus on technological enhancements and emerging challenges.

One notable area of progress involves the integration of sophisticated sensing and vision systems. 3D cameras and force/torque sensors have empowered robots to perceive and interact with their environment more effectively, while machine learning algorithms enhance object recognition capabilities. End-effector designs have also undergone refinement, with innovations like soft grippers and adaptive grippers improving gripping and manipulation efficiency. Additionally, the paradigm of collaborative robotics has gained prominence, with ongoing research dedicated to developing advanced safety mechanisms for human-robot interaction.

However, there are several challenges and future directions. Integration with Industry 4.0 remains a key focus, necessitating seamless connectivity with IoT and cloud computing while addressing concerns related to interoperability and data security. Cost-effectiveness and scalability are ongoing considerations, especially in small and medium-sized enterprises where affordable robotic solutions are in demand. The adaptability of pick and place robot arms to dynamic environments is also a critical area of research, emphasizing real-time path planning and decision-making in response to changes in the workspace.

Pick and place robot arms reflects a dynamic field marked by continuous technological progress. The potential transformation of manufacturing and logistics, driven by the integration of these robotic systems, hinges on addressing challenges such as cost-effectiveness, adaptability, and seamless integration with Industry 4.0 technologies. As research in this domain advances, the promise of enhanced efficiency, flexibility, and overall productivity in industrial applications becomes increasingly tangible.

III. Problem Statement

Four degrees of freedom robot arm which suitable for pick and place applications.

Develop a 4 degree of Freedom robotic arm tailored for pick-and-place tasks within confined environments. The design should prioritize cost-effectiveness, compactness, and safety. The robotic arm must integrate a sophisticated control system to ensure precise kinematic positioning and energy-efficient actuation. Emphasis should be placed on safety mechanisms to mitigate collisions and guarantee reliable operation. System evaluation will involve executing pick-and-place operations and examining performance metrics such as positional accuracy, speed, and adaptability to diverse objects, all within the defined spatial constraints.

Design an advanced end-effector for a robotic arm, aiming to improve its ability to handle different objects during industrial tasks. Focus on creating a versatile gripping mechanism using innovative materials, possibly soft robotics, and integrate sensors to provide instant feedback on force and touch. Evaluate the end-effector's performance in various assembly scenarios, prioritizing speed, reliability, and seamless integration with existing robotic systems.

IV. ROBOTIC ARM AND BASE DEVELOPMENT

The development of robotic arm and base is a strategic undertaking, leveraging advanced engineering principles and CAD tools. SolidWorks, a versatile computer-aided design (CAD) software, serves as the primary platform for creating precise 3D models that emulate the functionalities of a human arm. Our design process involves meticulous considerations for factors such as payload capacity, reach, and precision, all seamlessly manipulated within SolidWorks' parametric modeling environment. Articulating joints, selecting materials, and integrating electronic components are key aspects of the development, each facilitated by SolidWorks' robust capabilities. The iterative design approach enables swift adjustments, ensuring that the robotic arm and base meet stringent performance requirements. The documentation generated during this development process serves as a comprehensive guide for manufacturing and future enhancements. Ultimately, our project aims to realize an efficient and adaptable robotic system through the systematic development of its arm and base components.

A. Designing the Base

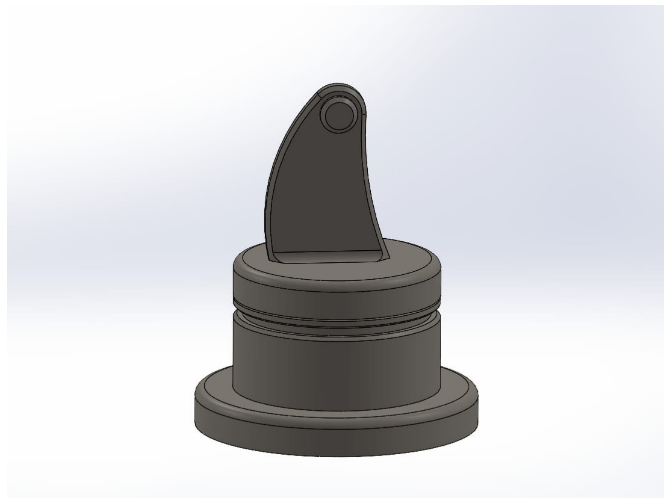

Fig. 5. Base

The base component of the robot provides structural support and serves as an attachment point for various other components. The link assembly is connected to the base via screws, allowing for rotation due to the operation of the motor. This rotation occurs at approximately 180 degrees. Additionally, brass standoffs are employed to securely fasten the supporting structures of the robotic assemblage. Furthermore, two motors are installed within the base, which are linked to the link through a series of mechanical connections.

Dimention = $20 * 15 * 8cm$

B. Designing the Link 1

The first link is serving as a conduit for the transmission of forces from one link to another through their connection via screws. These links are integrated with each other using a DC motor that facilitates their motion. Link 1 in the SolidWorks design of the pick-and-place robotic arm is characterized by a meticulous integration of robust yet lightweight structural elements, tailored to project-specific dimensions. Precision in material selection ensures durability and operational resilience, addressing stringent industry standards for surface finishes and tolerances. The design prioritizes optimal articulation and motion control, aligning with technical specifications to

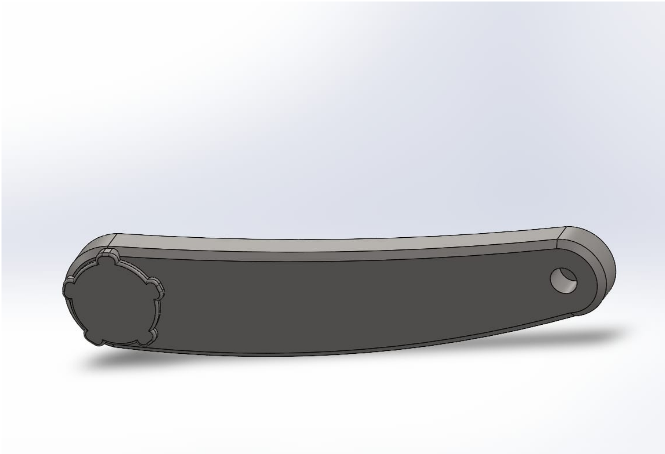

Fig. 6. Link 1

enhance overall efficiency and reliability in diverse industrial applications.

Dimention = $20 * 34 * 75cm$

C. Designing the Link 2

Link 2 in the SolidWorks design of the pick-and-place robotic arm is a vital connector, seamlessly bridging Link 1 and the gripper assembly. Its precise engineering prioritizes optimal alignment for synchronized movements within the robotic arm system. Tailored dimensions and robust material choices ensure resilience and strength, adhering to industry standards. Strategic surface treatments enhance operational precision, contributing to the overall efficiency and reliability of the pick-and-place robotic arm in diverse industrial applications.

Dimention = $20 * 34 * 7.5cm$

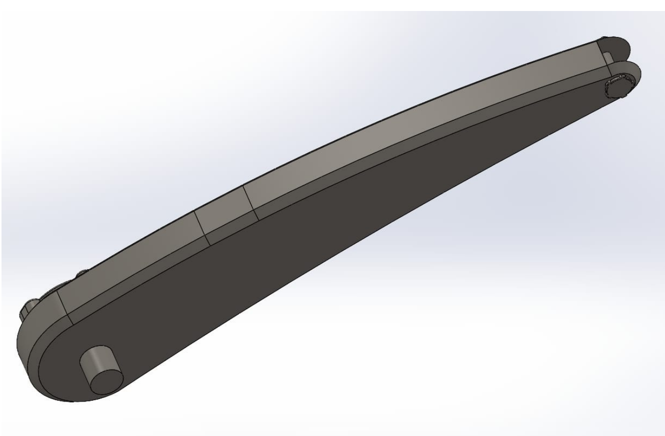

Fig. 7. Link 2

D. Designing the Gripper

The gripper constitutes a pivotal component in our project, embodying its significance in robotic manipulation and object handling. As an indispensable element of the robotic system, the gripper plays a key role in securely grasping and releasing objects. In our project, we carefully selected a gripper design tailored to the specific requirements of our application, considering factors such as actuation type, precision, and adaptability. The gripper's efficient functioning is paramount to the success of our project, as it directly influences the system's ability to perform intricate tasks with accuracy and reliability. The chosen gripper design aligns with our project goals and contributes significantly to the overall effectiveness of the robotic system.

Dimention = $18 * 20 * 6cm$

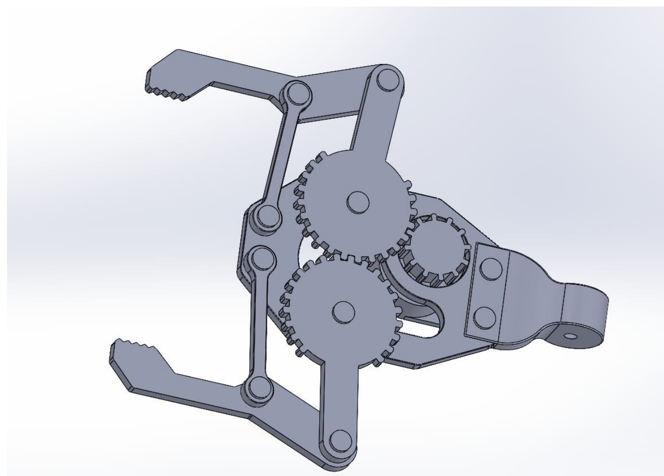

Fig. 8. Gripper

E. Assembly of Robot

The assembly of our robot is a methodical process involving the meticulous integration of various components. Beginning with the base, we systematically assemble motors, joints, sensors, and the end-effector to create a cohesive and functional robotic system. Attention to precision and detail is paramount as we secure components using fasteners and organize wiring for efficient electrical connections. Quality control is a key focus during assembly, with engineers conducting thorough checks on connections, joint movements, and sensor functionality. Once assembled and verified, the robot is poised for testing and subsequent operational deployment.

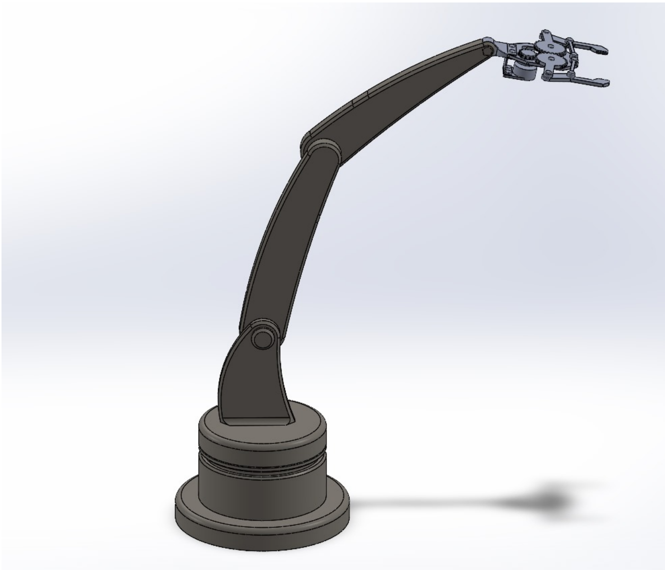

Fig. 9. Assembly of Robot

V. Methodology

The creation of the pickup and drop robot commenced with a thorough identification of functional requirements, encompassing payload capacity, range of motion, and operational speed. Initial conceptualization involved brainstorming sessions and rough sketches to envision the robot's design and functionality. Selection of appropriate materials, actuators, sensors, and other components was conducted in alignment with the specified requirements.

Subsequently, SolidWorks was utilized to construct a comprehensive 3D model of the robot, integrating chosen components into a coherent assembly. Simulation and validation within SolidWorks ensured the model's feasibility and performance, leading to iterative design modifications for optimization.

The transition to SimScape Multibody involved importing the SolidWorks model for detailed mechanical dynamics simulation. Constraints were defined, and forces were applied to emulate real-world conditions, ensuring an accurate representation of the robot's interactions during pickup and drop operations. Extensive simulations verified the model's performance, with parameters adjusted for precision and reliability.

The conversion of the SimScape Multibody model into a MATLAB Simulink file facilitated further analysis and testing. While control systems were not implemented in this phase, Simulink was used for system-level integration and testing of the mechanical model.

VI. Program Structure Design using MATLAB/Simulink

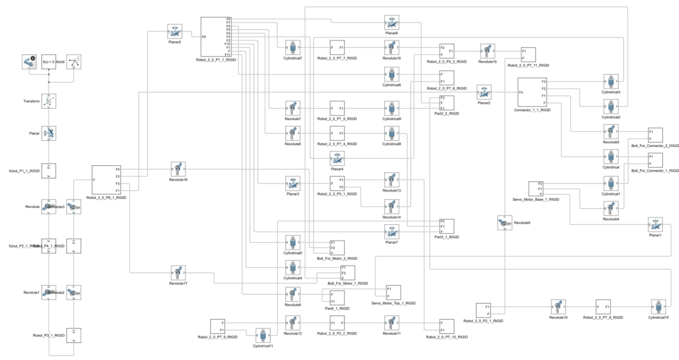

Fig. 10. Full Illustration

The MATLAB Simulink block diagram for the pick-and-place functionality of the robotic arm presents a detailed illustration of the system's operations. Utilizing interconnected blocks, the diagram outlines crucial elements such as motion planning, control algorithms, and actuator commands. This visual representation visually communicates the stepwise coordination of processes inherent to the pick-and-place operation, ranging from sensor-based data acquisition to the execution of precise movements.

The diagram establishes a structured framework for constructing the system and validates its efficiency through dynamic simulations. These simulations contribute to a comprehensive understanding of the intricate interactions within the pick-and-place application. In essence, the diagram serves as a detailed guide, facilitating the construction of the system and refinement of its performance through testing and optimization.

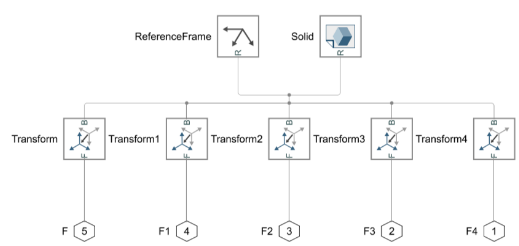

Fig. 11. Motor Connector

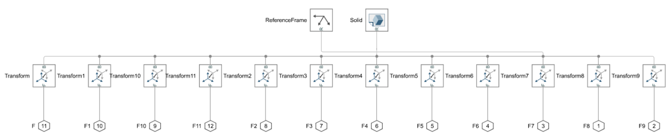

Fig. 12. Gripper Plate

VII. RESULTS

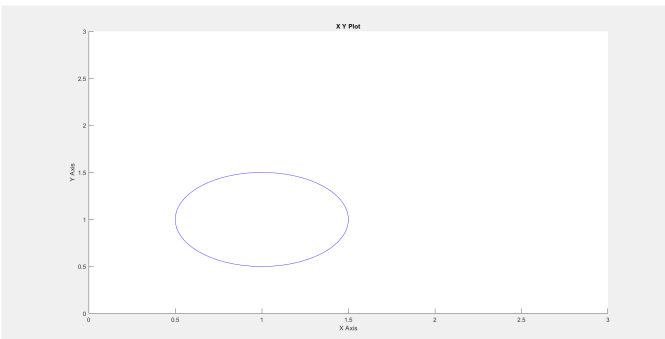

Fig. 13. Robot Arm's Circular Trajectory

This investigation delves into the domain of robotic kinematics, specifically examining the robot arm's adept navigation along circular paths. Through a meticulous analysis of graphical representations, we aim to unravel the complexities inherent in the precision and control exhibited during these circular trajectories. The provided graphs serve as visual testament to the system's ability to execute flawless circular motions, offering valuable insights into the mechanical intricacies at play. In exploring these graphical depictions, we endeavor to articulate a succinct yet insightful narrative, shedding light on the mechanical proficiency underpinning the robot arm's motion planning capabilities.

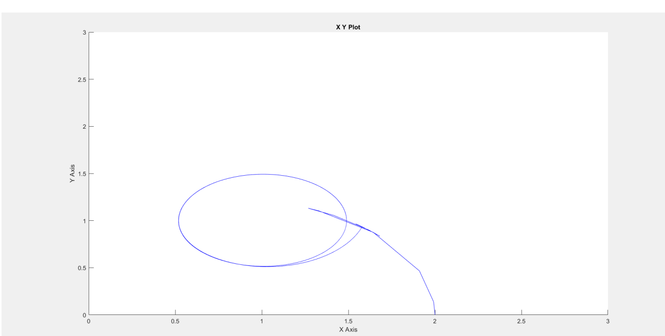

Fig. 14. Robot Arm's Circular Trajectory

VIII. REFERENCES

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