UNIVERSITI TEKNOLOGI MALAYSIA
Malaysia-Japan International Institute of Technology (MJIIT)

COMPUTER INTEGRATED MANUFACTURING (SMJE 4263)

PICK AND PLACE IN THE ASSEMBLY LINE

(GROUP PROJECT)

2022/2023 – 2

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Content

Introduction

In the quest for manufacturing excellence, industries have consistently sought methods to enhance productivity, accuracy, and cost-effectiveness. Among the most remarkable advancements is the Pick and Place Assembly Line, a cutting-edge manufacturing process that has been ingeniously integrated with computer machinery. This seamless amalgamation has set new benchmarks for efficiency, speed, and precision, revolutionizing the way products are assembled.

The Pick and Place Assembly Line is a highly automated manufacturing system that involves the precise positioning and placement of components onto a substrate to create intricate products. Traditionally, this process relied on human labor and required considerable time and effort, often leading to inconsistencies and human errors. However, with the integration of computer machinery, the assembly line now operates with unparalleled accuracy, eliminating manual intervention and optimizing every step of the production process.

In this introduction, we explore the transformative power of the Pick and Place Assembly Line with Computer Integrated Machines. We delve into the intelligent software algorithms that enable seamless communication between the assembly line's various components, such as robotic arms, conveyor belts, and sensors. This synergy of hardware and software not only streamlines the manufacturing workflow but also allows for real-time adjustments, adaptability to diverse product specifications, and increased overall efficiency.

Furthermore, we uncover the multifaceted advantages of this integration across a range of industries, from consumer electronics and automotive to medical devices and aerospace. As the demand for customizations and miniaturization rises, the Pick and Place Assembly Line with Computer Integrated Machines has emerged as the quintessential solution to meet the challenges of modern manufacturing. The assembly line's working principle is a hallmark of modern manufacturing, facilitating the streamlined and efficient production of goods at an unprecedented scale. At its core, the assembly line is a systematic and highly organized process that revolves around a continuous flow of materials and components, moving through a series of specialized workstations, each designated for a specific task. Standardization plays a pivotal role in this process, as it ensures that the product design and components remain consistent, thereby simplifying production and minimizing the chances of errors or inconsistencies.

One of the key strengths of the assembly line is its ability to leverage both automated machinery and manual labor effectively. Automation, with the aid of sophisticated robots and machines, accelerates the production process, while manual labor is reserved for tasks that require intricate human touch or decision-making. This careful integration of technology and human expertise results in an optimized production line that can handle a wide range of manufacturing needs, from high-volume, repetitive tasks to delicate, personalized assembly requirements. Incorporated into the assembly line are robust quality control measures. At various points along the line, rigorous inspections, tests, and checks are conducted to ensure that each product meets the required standards of quality and safety. These quality assurance processes safeguard against defects and faults, reducing waste and minimizing the likelihood of defective products reaching the hands of consumers.

Continuous improvement lies at the heart of the assembly line's success. Data analysis, feedback from workers and supervisors, and constant monitoring of production metrics allow manufacturers to identify bottlenecks and inefficiencies. Armed with these insights, they can refine the process, fine-tune operations, and make incremental adjustments to optimize productivity and reduce costs. This ongoing pursuit of improvement cultivates a culture of innovation within the manufacturing environment, driving progress and technological advancements. As products move through the assembly line, they undergo a gradual integration of components, culminating in a final assembly before being prepared for packaging and distribution. The seamless flow of materials and assembly steps ensures a steady and efficient pace, increasing production output and meeting consumer demands more effectively.

From the industrial revolution to the present day, the assembly line has revolutionized manufacturing, shaping the global economy and driving technological progress. It has become a symbol of efficiency and mass production, enabling industries to deliver products at scale while maintaining consistent quality. As the manufacturing landscape evolves, the assembly line continues to adapt and embrace advancements in automation, robotics, and digitalization, further solidifying its position as a fundamental pillar of modern manufacturing processes.

Problem Background

In the quest for increased efficiency and productivity, industries across the globe have integrated pick and place robots into their assembly lines. These sophisticated robotic systems offer unparalleled advantages in automating the intricate task of picking up components and precisely placing them in designated positions during the assembly process. However, along with the numerous benefits, the adoption of pick and place robots also presents various challenges that manufacturers must address to fully harness their potential. One of the primary challenges lies in the complexity of the assembly line itself. Different products and manufacturing processes require unique handling, making it essential to customize pick and place robots accordingly. This customization involves programming the robots with the precise movements, grip strength, and sensor feedback needed to handle the specific components efficiently. Adapting the robotic system to accommodate diverse product lines can be time-consuming and require skilled programming expertise.

Moreover, the speed and accuracy of pick and place robots are critical factors in meeting production targets and ensuring high-quality output. In fast-paced assembly lines, these robots must execute their tasks with precision, avoiding errors that could lead to costly rework or delays. Achieving the desired level of accuracy can be a technical challenge, as factors like sensor calibration, mechanical tolerances, and environmental conditions can impact the robot's performance. Another significant concern is the interaction between pick and place robots and human workers in a collaborative environment. As automation progresses, it becomes increasingly vital to ensure the safety of human employees working alongside these robots. Implementing robust safety protocols, such as sensor-based collision avoidance systems and proper training, becomes crucial to prevent potential accidents and maintain harmonious human-robot collaboration.

Furthermore, maintenance and system downtime can pose significant disruptions to the assembly line's smooth operation. Pick and place robots, like any complex machinery, require periodic maintenance and may experience occasional breakdowns. Minimizing downtime and optimizing maintenance procedures are vital to keep the assembly line running at full capacity and maximize the return on investment in robotic automation. Manufacturers are investing in advanced technologies like artificial intelligence and machine learning algorithms to address these challenges. These technologies enable pick and place robots to learn from their experiences, adapt to changing environments, and continuously improve their performance. Additionally, simulation software is used to model the assembly process and test robotic movements virtually, reducing the need for physical trial and error and expediting the robot customization process. Collaborative robotics is also gaining traction, where pick and place robots are designed to work safely alongside human operators. Innovative safety features, like force-sensing technology and sophisticated algorithms, allow the robot to detect human presence and automatically adjust its speed or path to prevent collisions.

Problem Statement

The integration of pick and place robots into assembly lines poses several challenges that manufacturers must address to maximize their benefits. Customization complexity requires time-consuming programming efforts and skilled expertise to adapt the robotic system for diverse product lines. Achieving high-speed operation and precise component placement demands advanced calibration and sensor feedback to avoid errors and delays. Ensuring safe human-robot collaboration necessitates robust safety protocols and collision avoidance systems. Maintenance and occasional breakdowns can disrupt the assembly line's efficiency, requiring optimized procedures to minimize downtime. Embracing advanced technologies like AI and simulation software enables adaptability and continuous improvement. Addressing these challenges will empower manufacturers to unlock the full potential of pick and place robots, enhancing productivity and quality in modern manufacturing.

Objectives

1. **Increased Production Efficiency**: CIM facilitates continuous production flow and minimizes downtime by automating the pick and place process. Robots equipped with advanced algorithms can handle repetitive tasks with speed and consistency, ensuring a steady workflow and higher production output.

2. **Real-Time Monitoring and Quality Control**: CIM provides real-time data monitoring and analysis, enabling manufacturers to track production metrics, identify bottlenecks, and implement corrective actions promptly. This enhances quality control and allows for continuous process improvement.

3. **Optimized Resource Utilization**: By integrating computers and automation, CIM optimizes resource allocation, such as materials, energy, and labor. This leads to cost savings and increased resource efficiency, making the manufacturing process more sustainable.

Literature Review

1. Automated material handling in composite manufacturing using pick-and-place systems [3].

Automated material handling using pick-and-place systems in composite manufacturing has emerged as a crucial area of research and development in modern manufacturing processes. The integration of advanced pick-and-place technologies, such as robotic arms and gantry systems, offers numerous advantages, including increased production efficiency, improved product quality, and enhanced workplace safety. A comprehensive review of the literature reveals the diverse applications of automated material handling in the composite manufacturing industry. Research studies have explored the implementation of intelligent pick-and-place systems, driven by machine learning algorithms, to optimize handling trajectories, adapt to varying material characteristics, and reduce cycle times. Real-time monitoring and quality control have also been investigated, highlighting the significance of integrating sensor technologies with pick-and-place systems for precise component placement and defect detection. Additionally, collaborative robotics, or co bots, have been studied for their potential to work alongside human operators, improving productivity and ergonomics. Despite the promising benefits, challenges related to material fragility, gripper design, and automation programming complexities remain. Nevertheless, the reviewed literature underscores the transformative impact of automated material handling in composite manufacturing and sets the stage for further advancements in this critical domain.

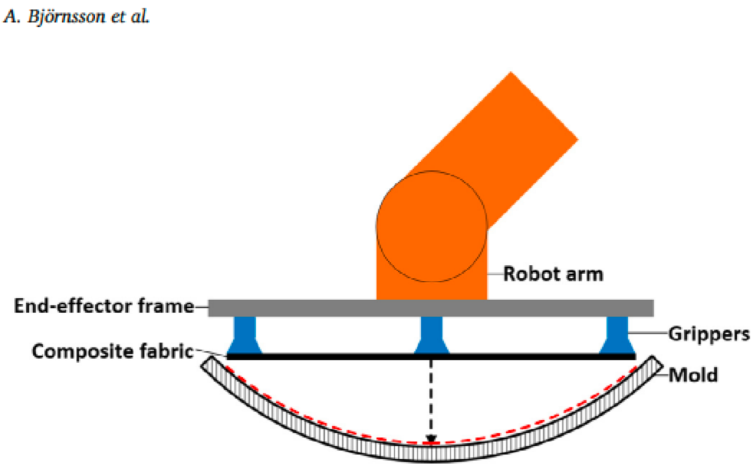

Figure 2.1 Deposition of material onto a 3D mold [3].

2. Multirobot coordination in pick-and-place tasks on a moving conveyor [4].

Multirobot coordination in pick-and-place tasks on a moving conveyor is a captivating area of research that addresses the complexities of synchronizing multiple robots to collaboratively handle objects on a dynamic conveyor system. This topic has gained significant attention in recent years as industries seek to optimize efficiency and throughput in manufacturing and logistics operations. The literature reveals several approaches to tackle this challenge. Researchers have explored decentralized control strategies, where each robot autonomously plans its actions based on local information and communicates with other robots to avoid collisions and optimize task allocation. Additionally, centralized coordination methods have been investigated, where a central controller coordinates the actions of multiple robots, taking into account the global conveyor movement and task priorities. Advanced sensing and perception techniques, such as computer vision and object tracking, have been integrated to enable robots to accurately perceive the conveyor environment and make informed decisions in real-time. Moreover, machine learning algorithms have been employed to adaptively learn from previous pick-and-place experiences, improving coordination efficiency and overall system performance. The literature highlights the potential benefits of multirobot coordination in pick-and-place tasks on a moving conveyor, including increased production rates, reduced cycle times, and the ability to handle complex and dynamically changing workloads. However, challenges remain in terms of collision avoidance, real-time coordination, and scalability to large-scale conveyor systems. Further research in this area will undoubtedly contribute to unlocking the full potential of multirobot systems, and revolutionizing automation in manufacturing and logistics industries.

Figure 2.2 Multirobot pick-and-place on a conveyor with two robots [4].

3. Computer Integrated Manufacturing [1].

Computer-Integrated Manufacturing (CIM) represents a ground-breaking paradigm in the field of manufacturing, where the seamless integration of computer-based technologies and automation converge to optimize production processes. This literature review delves into key aspects and advancements of CIM, highlighting its impact on efficiency, productivity, and quality in modern manufacturing systems. Numerous studies have underscored the transformative potential of CIM, showcasing its ability to enhance the synchronization of manufacturing operations, resulting in reduced lead times, minimized wastage, and increased flexibility in response to market demands. As evidenced by various research findings, CIM's incorporation of computer-aided design (CAD), computer-aided manufacturing (CAM), and computer-aided engineering (CAE) facilitates streamlined product development, enabling manufacturers to bring products to market faster and at lower costs. Moreover, CIM's integration of real-time data collection and analysis enables proactive decision-making, paving the way for predictive maintenance, resource optimization, and intelligent scheduling. Despite the considerable advantages, challenges related to implementation costs, workforce training, and system complexity remain prevalent, as highlighted in the literature. As conclusion, the literature emphasizes that while CIM offers immense potential for manufacturing industries, successful adoption requires careful planning, investment, and a skilled workforce to unlock its full transformative capabilities. As researchers continue to explore and refine CIM frameworks, this literature review underscores the importance of staying abreast of emerging technologies to sustain a competitive advantage in the dynamic landscape of modern manufacturing.

4. Development of a Practical Tool for Designing Multi-Robot Systems in Pick-and-Place Applications [2].

The development of multi-robot systems has garnered increasing interest in pick-and-place applications due to their potential to enhance productivity and efficiency in manufacturing and logistics industries. This literature review examines the advancements made in the creation of a practical tool specifically tailored for designing multi-robot systems in pick-and-place applications. Various research studies have investigated the challenges and complexities associated with such systems, including task allocation, motion planning, collision avoidance, and coordination among robots. These challenges necessitate a systematic approach to designing multi-robot systems that can adapt to diverse application requirements. Consequently, researchers have proposed novel algorithms and frameworks to address these issues, aiming to optimize task distribution among robots and ensure smooth and collision-free execution. Furthermore, the literature reveals that the development of the practical tool has often leveraged computer-aided design (CAD) and simulation tools to model and validate the multi-robot systems' performance in pick-and-place scenarios. The tool's effectiveness is also assessed through experimental setups and real-world implementations, demonstrating its viability and benefits for industry applications. Despite the progress made, the literature indicates that certain aspects, such as scalability, real-time adaptability, and human-robot interaction, remain areas of active research and improvement. As the field evolves, the literature underscores the importance of continued efforts to refine the practical tool, making it more user-friendly, robust, and versatile, ultimately contributing to the widespread adoption of multi-robot systems in pick-and-place applications across various industries. In conclusion, this literature review highlights the significant strides made in the development of a practical tool for designing multi-robot systems and identifies key research directions that hold promise for future advancements in this field.

Methodology

This project utilizes two platform which are Factory I/O and TIA Portal. Factory I/O was chosen to provide the scene needed to simulate a real 3-D environment of assembly line inside a factory. In addition, the programming for the pick and place was done on TIA Portal using ladder logic.

Figure 3.1 shows the scene of assembler system completed with the pick and place robot. The machine is equipped with a control panel box to automatically or manually initiate the system. Here, we use ladder logic to control the sequence for the assembly machine of bases and lids.

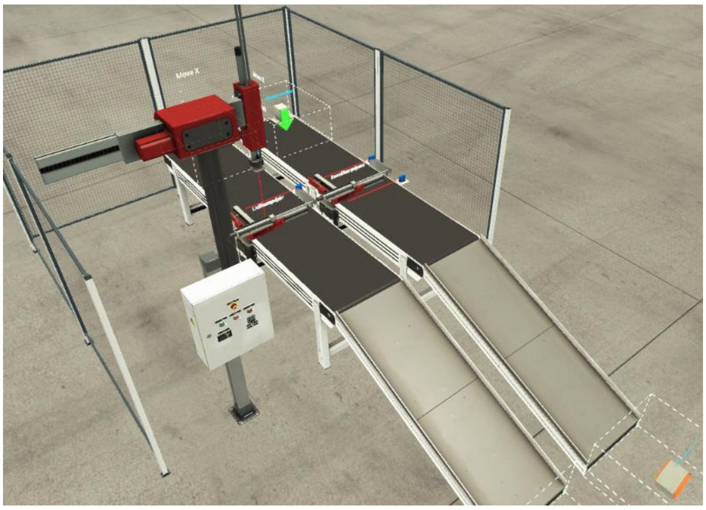

Figure 3.1 Assembler inside Factory I/O

Figure 3.2 shows the control panel box to control the system. In manual state, every time the start button is pushed, the machine will initiate a step by step process from letting both base and lid to the designed place, clamping, picking the lid and combines it to the base product. This process need the start button to be pushed consequently to complete the cycle.

Figure 3.2 Control box for the assembler machine

In order to program the assembler system, we installed TIA Portal V17 and other related software to build the ladder logic diagram for the system. Figure 3.3 until Figure 3.5 show some of the initial sequence for the system which when the push button was initiated, the sequence will run step by step throughout the whole program.

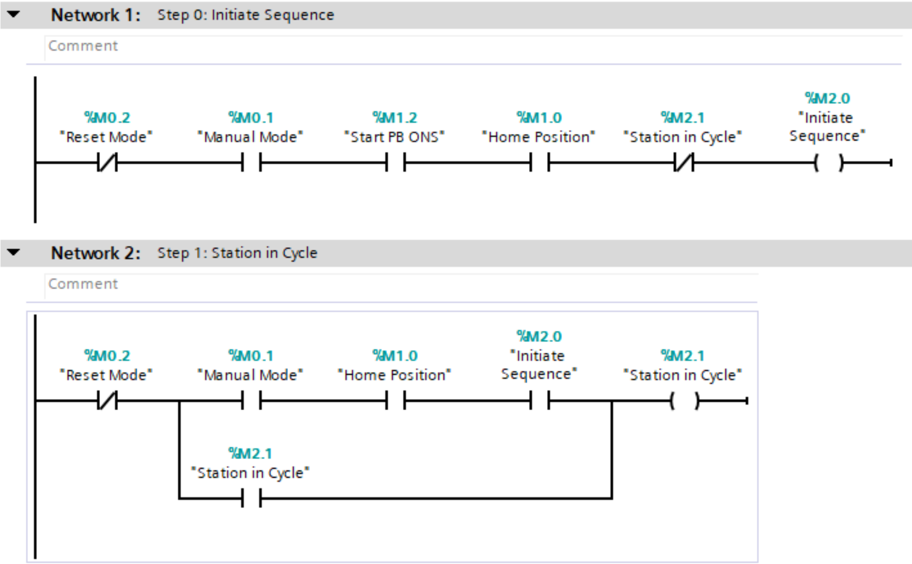

Figure 3.3 Ladder diagram 1

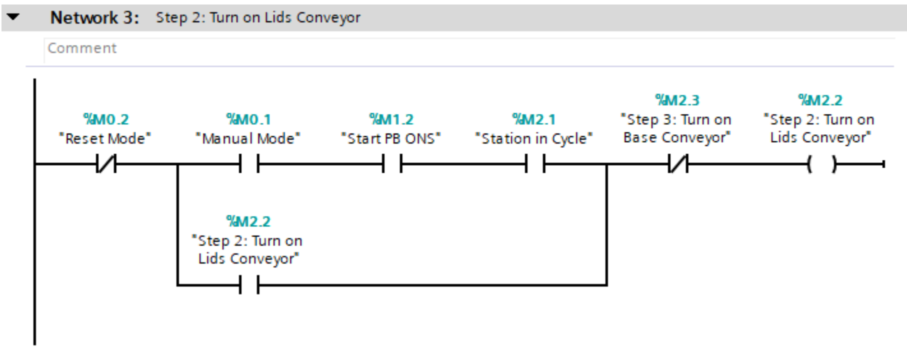

Figure 3.4 Ladder diagram 2

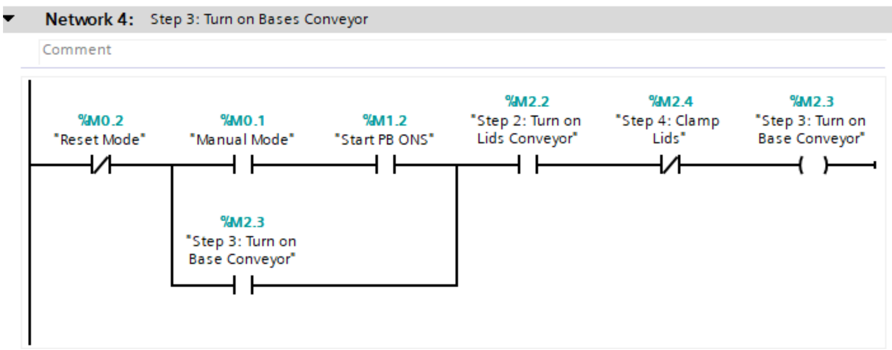

Figure 3.5 Ladder diagram 3

Result

From the programming inside the TIA Portal, our project succeeded in running the sequence of assembling the product consisting of pick and place machine. Figure 4.1 shows the initial position of the system whereas both lid and base on conveyors are placed between the clamper.

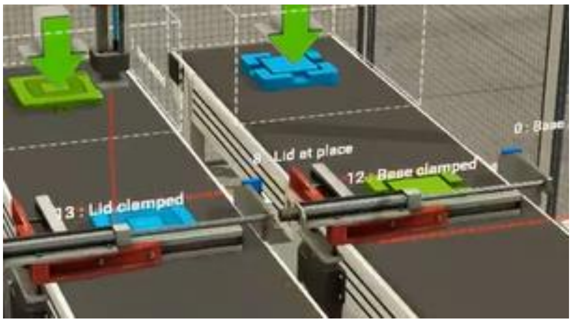

Figure 4.1 Initial Position of lid (blue) and base (green)

The lid and base were then clamped to secure a safe position before proceeding to the next step as showed in figure 4.2. Then the Z-axis of the pick and place machine was extended to grab the lid on the lid conveyor as shown in Figure 4.3.

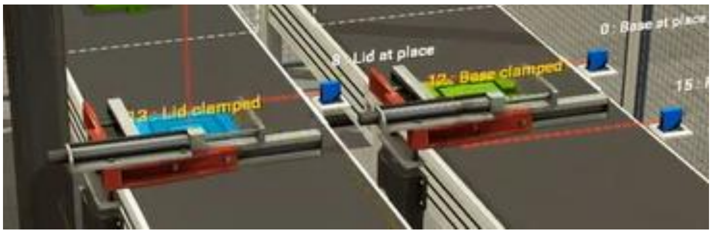

Figure 4.2 Lid and Base clamped

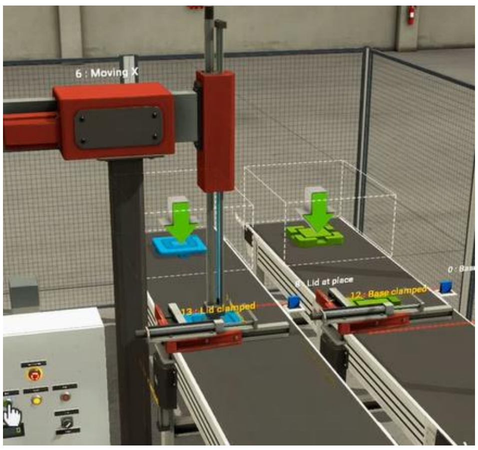

Figure 4.3 Grabbing lid on lid conveyor

After grabbing, the machine will pass the lid to the base conveyor and assemble both lid and base as one product. Figure 4.4 shows the machine assembling the product and Figure 4.5 showing the Z-axis of the machine retracting after the product being assembled.

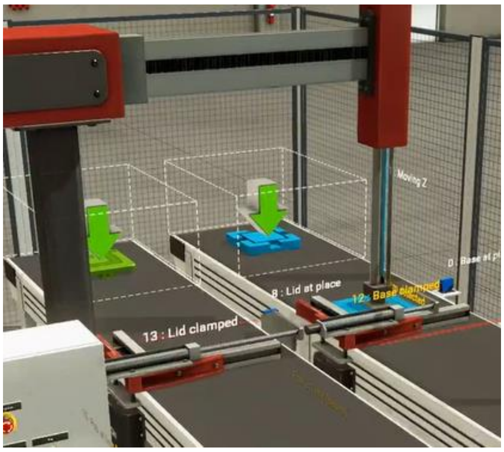

Figure 4.4 Lid was assembled with the base

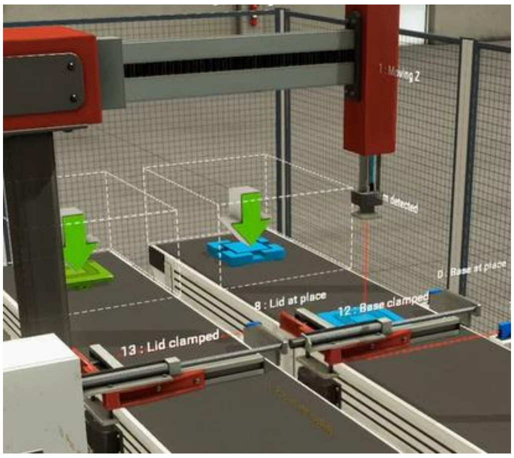

Figure 4.5 Retracting Z-axis.

Then, the clamp on the base conveyor will move up allowing the product to pass a sensor. Passing the sensor would initiate the pick and place machine to reset its position to the initial position just above the lid conveyor to proceed to the next cycle of production. Figure 4.6 shows the final position after the product leave the clamp and sensor before being sorted as the next step of production line.

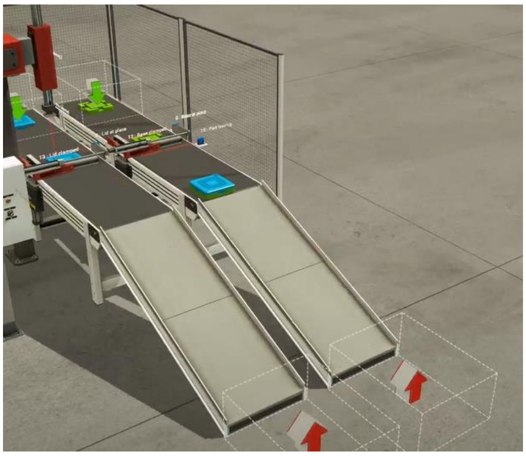

Figure 4.6 Final position of the assembled product

Future Improvement

1. LUMA AI.

LUMA AI represents an innovative approach to artificial intelligence and automation, providing advanced solutions for various industries. Leveraging cutting-edge technologies, LUMA AI streamlines processes, optimizes operations, and enhances decision-making capabilities. However, as with any evolving technology, there are opportunities for future improvements. In the context of our project, our aim is to design a three-dimensional structure of a pick and place robot for simulation in assembly line scenarios. By integrating LUMA AI's intelligent algorithms with this 3D model, we intend to create a comprehensive simulation platform that can predict and optimize the robot's performance in different assembly line configurations. This simulation will aid in identifying potential bottlenecks, refining motion planning, and enhancing overall efficiency. Moreover, the integration of real-time data analysis and predictive capabilities will empower the robot to adapt dynamically to changing assembly line conditions, further optimizing its movements and increasing productivity. Our project also emphasizes the importance of user-friendly interfaces, allowing engineers and operators to interact seamlessly with the simulation and make informed decisions based on real-time insights. Furthermore, we aim to explore potential synergies between LUMA AI's capabilities and the latest advancements in robotic hardware, such as sensors and actuators, to achieve a more comprehensive and efficient pick and place system. As we continuously refine and expand our project, we envision a future where the combination of LUMA AI's intelligence and our 3D simulation of the pick and place robot will revolutionize assembly line operations, promoting increased productivity, reduced downtime, and optimized resource utilization in manufacturing and logistics industries.

Figure 5.1 Luma AI Logo.

2. NVIDIA Omniverse platform.

Nvidia Omniverse represents a groundbreaking platform that revolutionizes the world of computer graphics and simulation. By providing a collaborative and interactive 3D environment, Omniverse enables real-time rendering, visualization, and simulation of complex scenes and scenarios. As we embark on our project to conduct assembly simulations, we plan to leverage the power and versatility of Nvidia Omniverse to enhance the efficiency and accuracy of our simulations. The platform's physics-based rendering and simulation capabilities will allow us to create realistic and dynamic virtual environments, where we can model intricate assembly line processes with precision. Additionally, Omniverse's collaborative features will enable seamless teamwork, allowing multiple stakeholders to interact and collaborate in real-time during the simulation design phase. As we look towards future improvements, our project aims to incorporate AI-driven automation into the assembly simulation process. By integrating advanced AI algorithms with Omniverse, we seek to optimize assembly workflows, identify potential bottlenecks, and predict performance outcomes. This AI-driven approach will provide valuable insights and recommendations, leading to further optimization of assembly line processes and increased productivity. Furthermore, we aim to explore the integration of sensory data from physical robots into the Omniverse platform, enabling a closed-loop simulation environment. By connecting the virtual and physical worlds, we can achieve a higher degree of accuracy and fidelity in our assembly simulations, facilitating the development of more efficient and reliable robotic systems. Overall, with Nvidia Omniverse as our cornerstone, our project endeavors to redefine assembly line simulation by embracing cutting-edge technologies and driving innovation towards more streamlined, intelligent, and collaborative manufacturing processes.

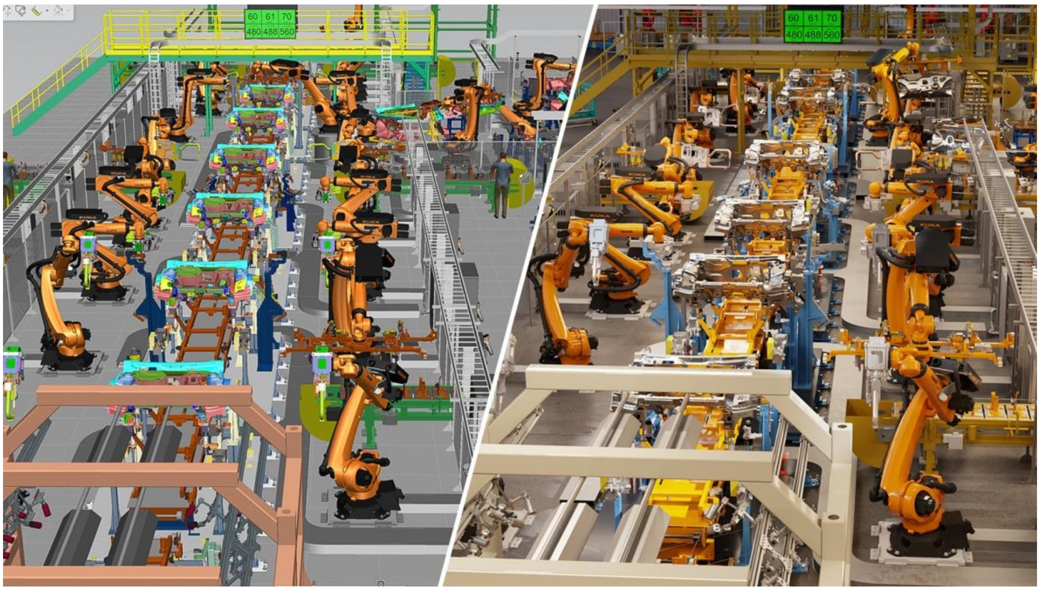

Figure 5.2 Assembly line simulation in NVIDIA Omniverse.

3. Blender and LUMA AI

In the pursuit of future improvements for our assembly simulation project, we envision a seamless integration of Blender, LUMA AI, and Nvidia Omniverse to create a powerful and comprehensive simulation platform. With Blender's advanced capabilities in 3D modeling and animation, we plan to streamline the process of importing the 3D design of the pick and place robot, generated by LUMA AI, into the simulation environment. Blender's versatility will enable us to fine-tune and optimize the robot's 3D model, ensuring an accurate representation of its physical characteristics and movements. Through the integration of LUMA AI and Blender, we can also enhance the robot's behavioral aspects within the simulation. By leveraging LUMA AI's AI-driven algorithms, we aim to imbue the pick and place robot with intelligent decision-making capabilities, enabling it to adapt dynamically to changing assembly scenarios. This integration will facilitate realistic and sophisticated simulations, closely mimicking the robot's real-world behavior and interactions with other components in the assembly line.

Furthermore, combining Blender with Nvidia Omniverse will open up new horizons for visual fidelity and realism in the simulation. Omniverse's physics-based rendering and real-time visualization capabilities will complement Blender's advanced rendering engine, providing stunningly realistic visualizations of the assembly process. The collaborative nature of Omniverse will allow engineers and stakeholders to observe the simulation from multiple angles and perspectives, facilitating better understanding and informed decision-making. In conclusion, our project's future improvements, incorporating Blender for simulation and LUMA AI for 3D design, aim to create a cutting-edge assembly simulation platform that fuses the best of 3D modeling, AI-driven intelligence, and real-time rendering. This integration will revolutionize the way we approach assembly line simulations, empowering manufacturers and engineers with valuable insights, optimizations, and cost-effective solutions to drive innovation and efficiency in manufacturing processes.

Conclusion

In conclusion, the development of the Pick and Place system using Computer-Integrated Manufacturing (CIM) concepts represents a significant milestone in the evolution of modern assembly line processes. The integration of advanced technologies, such as computer-aided design (CAD), computer-aided manufacturing (CAM), and computer-aided engineering (CAE), has enabled the creation of a highly efficient, flexible, and intelligent robotic system. The implementation of CIM has revolutionized traditional assembly line operations, enhancing productivity, accuracy, and overall performance. Through the utilization of CIM, the Pick and Place system can seamlessly adapt to varying production demands, thereby reducing lead times and optimizing resource utilization. The system's real-time data collection and analysis capabilities enable proactive decision-making, predictive maintenance, and continuous process improvement, leading to minimized downtime and enhanced quality control.

Moreover, CIM fosters a collaborative environment, where human operators and robots work synergistically to achieve higher levels of efficiency and precision. The integration of human-robot interaction ensures safety and simplifies the programming and control of the Pick and Place system, making it more accessible to operators of varying skill levels. While the development of the Pick and Place system using CIM has yielded remarkable results, there are still opportunities for further enhancements. Future advancements may involve integrating Artificial Intelligence (AI) algorithms to enable self-learning and adaptive behavior, allowing the system to continuously optimize its operations in response to dynamic production scenarios. Additionally, the implementation of CIM in the Pick and Place system paves the way for seamless connectivity with other manufacturing systems, fostering a truly interconnected and smart factory environment. This integration facilitates efficient communication between different production stages and enables data-driven decision-making at a higher organizational level.

To conclude all, the development of the Pick and Place system using Computer-Integrated Manufacturing principles has revolutionized assembly line operations. The synergy of cutting-edge technologies, real-time data analysis, and human-robot collaboration has resulted in an agile, efficient, and intelligent system capable of meeting the demands of modern manufacturing industries. As research and innovation in CIM continue to progress, the future promises even more transformative developments in the realm of assembly line automation, driving manufacturing industries toward greater productivity, sustainability, and competitiveness.

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