SYMBIOSIS INSTITUTE OF TECHNOLOGY

ROBOTICS AND AUTOMATION DEPARTMENT

# Class: M. Tech Robotics and Automation Batch: 2022-24

# Project Title: Guided Assembly Station with Machine Vision

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# 1.0 Introduction

## 1.1 What are Guided Assembly Stations?

In today's highly competitive manufacturing landscape, the pursuit of efficiency, accuracy, and quality in production processes has become paramount. Guided assembly stations has gained significant attention in the reccent years. These specialized workstations leverage technology to provide assembly line workers with step-by-step instructions, visual aids, and real-time feedback, revolutionizing how complex products are manufactured. Guided assembly stations have emerged as a powerful tool to enhance productivity, reduce errors, and ensure consistent product quality. This research work explores guided assembly stations' principles, applications, and impact on modern manufacturing. It highlights their role in transforming traditional assembly processes into streamlined, error-resistant, and adaptable workflows.

**1.1.1 The Core Components of Modern Guided Assembly Systems:**

Guided assembly systems rely on a seamless interplay of various technologies to achieve efficient and accurate production. Meticulous planning lays the groundwork, outlining the assembly sequence and ensuring error-free execution. Detailed work instructions guide operators or automated systems, guaranteeing that each task is performed correctly and in the designated order. Machine vision integration plays a crucial role, utilizing advanced visual technologies to verify part positions, detect defects, and ensure precise component placement. Real-time feedback is provided by a network of sensors and feedback systems, allowing for swift identification and resolution of any potential issues.

Quality assurance measures are embedded throughout the process, ensuring every component meets specified standards and minimizing the risk of defects.

Further safeguards come in the form of error prevention and correction features. Interlock systems help prevent mistakes during assembly, while mechanisms are in place to rectify any errors that do occur. The system offers training modules and support to empower operators, ensuring they can confidently operate and troubleshoot the system effectively. Finally, user-friendly interfaces promote intuitive interaction and easy troubleshooting, making the system accessible and efficient for all users. By integrating these diverse technologies, modern guided assembly systems deliver enhanced accuracy, improved efficiency, and superior quality control, ensuring a smoother and more reliable production process.

## Machine Vision

Machine Vision endows machines with the ability to perceive and understand visual information, mirroring human vision capabilities. At its core, Machine Vision integrates sophisticated cameras, sensors, and computational algorithms to imbue machines with the power of sight. This revolutionary technology enables automated systems to " see," understand, and respond to their visual surroundings. By leveraging image processing and pattern recognition, Machine Vision empowers machines to make informed decisions based on visual data analysis.

Machine Vision is pivotal when it comes to automation, inspection as well as in quality control in industrial applications. From identifying defects in manufacturing lines to guiding robotic arms with precision, Machine Vision enhances efficiency, accuracy, and reliability across various industries. Machine Vision redefines how machines perceive and interact with the visual aspects of their environment. It is a fusion of optics, imaging, and artificial intelligence where machines can perceive, understand, and interact with the physical world accurately and quickly.

### Different Aspects Of Machine Vision

Machine vision takes the first step by acquiring high-quality images through cameras or sensors. To ensure reliable results, these images must be clear and noise-free. Raw images may undergo preprocessing, which involves enhancing their quality through noise reduction and lighting conditions adjustments. Once the image is prepared, the magic happens. Feature extraction involves identifying and isolating key elements like shapes, colors, and textures that hold valuable information. These features are then fed into recognition algorithms, where learned patterns allow the system to distinguish objects or identify specific conditions; by analyzing these features and recognized patterns, complex image analysis extracts meaning and knowledge from the visual data, enabling accurate decision-making. Object detection and localization pinpoint the position and orientation of objects within the image, a crucial skill for tasks like robotic guidance and automated inspection. Based on learned patterns, the system can also classify objects into different categories, enabling applications like quality control where defective items are automatically flagged.

Some systems utilize 3D vision technologies for even more depth, measuring depth and facilitating tasks requiring spatial understanding. This information seamlessly integrates with automated systems like robotic arms or assembly lines, boosting efficiency, speed, and precision in industrial settings.

The power of machine vision doesn't stop there. Real-time processing enables quick decision-making and responses, which is essential for dynamic environments and fast-paced settings. With advancements in AI, deep learning and neural networks empower systems to learn and adapt to complex visual scenarios, making them even more versatile. Additionally, human-machine interaction allows systems to interpret and respond to human gestures and expressions, facilitating intuitive interaction.

From quality control and inspection to real-time automation and human-machine partnerships, machine vision's diverse applications unlock the power of sight and transform how we see and interact with the world around us.

# 2.0 Literature Review

Ong Kok Meng [1] investigated a robotic arm system integrated with computer vision for object sorting based on color. The system employed a 5-DOF robotic arm, image processing for object recognition, and a modified flower pollination algorithm for inverse kinematics. Their findings demonstrated successful object detection and sorting based on color. Huang, J [4] presented a comprehensive review of existing methods for identifying and monitoring the loosening of threaded fasteners. They classified the methods into three categories: sensor-based, vision-based, and percussion-based. [8] introduced a Deep CNN architecture to assist in image classification. Their Convolutional Neural Network was trained on the extensive ImageNet dataset, encompassing various images that facilitated its learning process. The results demonstrated the network's effectiveness in image classification tasks. Manikandan, R. [12] explained a vision-based solution for detecting missing fasteners on rail track images using a support vector machine (SVM) classifier. This method first segmented the fasteners in the images and then extracted features like shape, size, and texture before using an SVM classifier to identify missing or present fasteners. The results showed the method's effectiveness in detecting missing fasteners. Gong, H. [13] proposed a computer vision integrated deep learning system to detect and count loosening of threaded fasteners. The method used a deep learning model to identify nuts and bolts and then geometric imaging theory to measure nut rotation angles. Their R-CNN based approach achieved accurate detection and identification of loosening. Yuan, C. [14] proposed a near real-time bolt-loosening detection method. Their R-CNN, trained on a dataset of bolt images with different loosening degrees, achieved accurate real-time bolt loosening detection. Pham, H.C. [15] introduced a novel approach for monitoring bolt loosening, combining image-based deep learning for nut and bolt detection with a graphical model to track their movement over time. Their framework proved effective in monitoring bolt loosening. Espinosa Peralta [20] explored the development of a vision system for fastener detection and localization. This system leveraged cameras and diverse image processing algorithms to achieve accurate identification and positioning. The article also emphasized the importance of socket wrenches, camera calibration, active NIR illumination, segmentation neural networks, and image augmentation for enhancing system robustness. Luscher, A. [22] discussed the application of machine vision technology for fastener identification and verification during assembly processes. This technology, utilizing cameras and recognition software, offered reliable verification by identifying unique features around fasteners, potentially eliminating the need for torque checks and reducing assembly costs. While the study demonstrated its reliability under simulated lighting, it did not explore industrial camera hardware. Sága, M., et al. [23] analyzed the development and performance of a robotized screwing application with an integrated vision system for the automotive industry. The article highlighted the crucial role of technical equipment, precise condition analysis, and engineering expertise for successful implementation. It emphasized the vision system's role in providing data on part shape and position and discussed the importance of selecting appropriate light sources and filters. Finally, it concluded by underscoring the integration of various systems in automated manufacturing lines. K., Köcher, S., et al. [24] envisioned a future factory transformed by technological advancements. This transformation would involve replacing rigid layouts and human-intensive processes with driverless transport systems and dexterous robots capable of complex tasks and data collection. The article envisioned seamless collaboration between humans and robots, streamlining production while ensuring safety. Lee, D., et al. [27] presented a robot with 2D vision and a gripper, controlled by a PLC, for inspecting and removing defective products on a conveyor belt. While achieving 95% accuracy on test pieces, it required further development to handle real-world variations and wider defect types. This research demonstrated the potential of integrating robots, vision, and PLCs for improved quality and productivity in manufacturing. Abhijith, V. S.[31] discussed the use of AprilTag markers in robotic applications. This marker system, utilizing barcodes, allowed for obtaining 6 DOF localization features from a single image. The paper described the experimental setup and highlighted the benefits of using AprilTag markers in robotic applications. Riedel et al. [33] proposed a deep learning-based worker assistance system for manual assembly. The study aims to provide architectural and implementational details of a state-of-the-art assembly assistance system based on an object detection model. The proposed system can prevent 51% of the assembly errors compared to a control group without the use of assistance. Hercog et al. [35] developed a product assembly assistance system based on Pick-To-Light (PTL) modules. The enclosure of the PTL modules is made of a PLA compound using a 3D printer. The system is scalable and can easily be upgraded to a larger number of module. The proposed system is useful in the case of the assembly process of complex products containing a large number of components. The paper concludes that the proposed assembly assistance system is designed to be universal and does not affect the worker in any undesirable way. [36] explores a product assembly assistance system based on Pick-To-Light (PTL) modules. The enclosure of the PTL modules is made of a PLA compound using a 3D printer. The system is scalable and can easily be upgraded to a larger number of modules. The paper also discusses the concepts of Cyber-Physical Systems (CPS), Internet of Things (IoT), and cloud computing. The proposed system is useful in the case of the assembly process of complex products containing a large number of components. Mishra et al. [38] analyzed the impact of downscaling images on edge detection. The paper explains that images are often downscaled to fit the aspect ratios of display devices, but this can lead to blurring of the edges, which are important for human visual perception. Lynn et al. [39] explores edge detection, which is a process used in image processing and computer vision to capture useful properties of objects and images. The authors compare the Canny and Sobel algorithms for edge detection and analyze the results obtained from each algorithm. The paper concludes by discussing the importance of real-time edge detection in various fields of life. Abdulhamid et al. [41] presented a computer vision system based on Raspberry Pi. The system uses Python programming language and OpenCV software to detect and count objects within a target area. The paper explains the factors that affect the system's reliability, such as the number of objects within an image, the background color, the distance between objects, the shadow of objects, and the distance from the camera's lens to the specimen. The paper concludes by highlighting the potential of the Raspberry Pi-based system and its ability to differentiate between objects in an image based on their shapes.

# Research Gaps.

# Lack of a complete & cost-effective guided assembly solution for the comparatively smaller companies. Existing machine vision-assisted guided assembly systems remain cost-prohibitive for smaller companies, hindering automation adoption and restricting access to advanced assembly solutions.

# Most of the authors have presented only simulation-based results. The proposed work aims for real-time implementation in the industry.

# Lack of flexibility in existing systems because they cannot handle various workpieces.

1. Smaller companies lack a readily available, cost-effective guided assembly solution, limiting their ability to compete with larger players who leverage automation for improved efficiency and quality. The benefits of adopting guided assembly stations in small-scale industries need to be analyzed.

# 3.0 Objective

1. To develop a vision-based system to simultaneously identify screw holes and track the nut runner position during the assembly process.
2. To use the computer vision system to display the required screwing sequence and verify the presence of each screw after its placement. (Auditory feedback if he goes to the wrong screw).
3. To integrate real-time visual feedback with the main controller, guiding the worker toward precise assembly.

# Scope And Limitation

# Computational time

# Accuracy

# Architecture Diagram

# Methodology - How am I going to do the three objectives?

# Tool and techniques

# Software

# Workflow

Start

Proof Of Concept

Alpha Prototype

Component Selection and Procurement

Visual Feedback (Monitor)

Establishing PLC – Microcontroller connection

Final System Hardware

Acquire Software Skills

Documentation

End

Documentation

Literature Survey

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Serial No.** | **Work Distribution** | **Time in Month** | | | | | |
| 11th November To  31st November | 1st December  To  31st December | 1st January To  31st January | 1st February  To  20th February | 20th February  To  15th March | 1st  April To  15th June |
| **1** | Literature Survey |  |  |  |  |  |  |
| **2** | Acquire Software Skills |  |  |  |  |  |
| **3** | Proof Of Concept |  |  |  |  |  |
| **4** | Alpha Prototype |  |  |  |  |  |  |
| **5** | Components Selection and Procurement |  |  |  |  |  |  |
| **6** | PLC – Microcontroller Connection |  |  |  |  |  |
| **7** | Visual Feedback (Monitor) |  |  |  |  |  |  |
| **8** | Final system – Hardware |  |  |  |  |  |  |
| **9** | Testing |  |  |  |  |  |  |
| **10** | Research Paper |  |  |  |  |  |

# 5.0 Timeline

**Bill Of Materials**

**The company provides all materials.**

|  |  |  |
| --- | --- | --- |
| ITEM | QTY | PRICE (in INR) |
| Camera | 1 | 3000 |
| Camera Mount | 1 | 500 |
| Monitor (AOC) | 1 | 6000 |
| PLC (s7 -1200) | 1 | 30000 |
| Raspberry PI | 1 | 5500 |
| Heat Sink for RPi | 1 | 300 |
| Proximity Sensor | 3 | 600 |
| Ethernet Cable | 1 | 200 |
| Torque Feedback Sensor | 1 |  |
| Barcode Scanner |  |  |
| Miscellaneous |  |  |
| Total |  | 51000 |

# Conclusion

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