Intelligent Object Recognition and Manipulation for Warehouse Automation Using SCARA Robot and Machine Vision System

Muthu Sai Charan V R[1], Sam Nithin P[2], Nithiskumar P[3] , Vydeeskumar R[4]

[1]Department of Mechnical Engineering, Saranathan college of Engineering
[2]Department of Mechnical Engineering, Saranathan college of Engineering
[3]Department of Mechnical Engineering, Saranathan college of Engineering
4Department of Mechnical Engineering, Saranathan college of Engineering

---***---

Abstract - Intelligent automation and robotics have the potential to revolutionize warehouse operations by improving efficiency and accuracy in object recognition and manipulation. This paper focuses on developing an intelligent system for recognizing and manipulating objects in real-time within a warehouse environment. The objective is to investigate advanced computer vision algorithms for real-time object recognition and design effective robot manipulation strategies for accurate sorting. The proposed methodology includes a thorough literature analysis, algorithm creation for object recognition, robot construction and integration of systems. The expected outcomes include the creation of an intelligent system capable of real-time object recognition and manipulation. This research aims to address the challenges in warehouse environments and provide valuable contributions to the logistics sector.

***Key Words*: Intelligent automation, robotics, computer vision, object recognition, manipulation, warehouse, efficiency.**

1.INTRODUCTION

In industrial settings, automation plays a vital role in improving productivity, accuracy, and reducing errors. One of the most popular automation techniques is the use of robots, specifically, SCARA (Selective Compliance Assembly Robot Arm) robots, which are widely used in industrial applications due to their high speed, accuracy, and repeatability. In this project, we aim to construct a 4-DOF (degree of freedom) SCARA robot with a machine vision system for quick and accurate pick-and-place tasks during inspection.

A. Robot

SCARA robots have become a popular choice for industrial settings due to their adaptability, speed, and accuracy. With their horizontal reach and swift movements, these robots are highly efficient in pick-and-place tasks and are well-suited for confined spaces. Our project aims to develop a 4-DOF SCARA robot that can carry out pick-and-place operations rapidly and precisely. The robot's design features four degrees of freedom to enable movement in four directions [5]. Our cost-effective approach involves 3D printing, which ensures the robot's durability and dependability. The robot's components include a base for stability, the arm with multiple segments and joints for maneuvering, and the end effector that interacts with the objects. Our chosen end effector is a gripper.

B. Machine Vision

Machine vision has become a crucial technology in automating industrial processes, as it uses cameras and algorithms to extract information from images, enabling robots to recognize objects, inspect products, and navigate their surroundings [6] . Our project involves utilizing a machine vision system comprising a camera that captures images of the workspace and an image processing algorithm that analyzes the images to determine the objects' dimensions. Our code for the machine vision system consists of multiple stages. Firstly, the camera captures a workspace image that is converted to grayscale. Then, to reduce noise, a Gaussian blur is applied to the image. The Canny edge detection algorithm is utilized to detect the object's edges in the image. The object's contours are then extracted, and the algorithm identifies the object with the most substantial area. The object's height and width are calculated using the known distance between the camera and the object and the camera's focal length. Lastly, the algorithm assesses whether the object is appropriate for pick-and-place operations based on its height, width, and circularity.

C. Application

The incorporation of the SCARA robot and machine vision system can provide various benefits in industrial settings, including the ability to carry out inspection tasks. The machine vision system can detect product defects and identify items that do not meet the required standards, allowing the robot to remove them from the production line, thus enhancing the output's quality[1]. Furthermore, the robot can perform pick-and-place operations accurately and rapidly, which is advantageous for repetitive tasks like assembling products. By automating these activities, the robot can increase productivity and decrease the likelihood of errors.

D. Significance and Novelty

The proposed project of developing a 4-DOF SCARA robot with a machine vision system holds great significance in the field of industrial automation, as it seeks to automate the time-consuming and error-prone manual handling of objects in industrial settings. What sets this project apart is the integration of a machine vision system with a SCARA robot for precise and efficient pick-and-place tasks. This system involves a high-resolution camera and image processing algorithms to identify objects' dimensions, while an Arduino is used to integrate the robot and camera. By utilizing 3D printing technology to manufacture the robot, this project presents a novel solution that improves productivity, accuracy, and efficiency while reducing errors in industrial settings. The integration of these technologies creates an innovative solution that has the potential to revolutionize industrial automation.

2. RELATED WORKS

"Vision-guided robot system for automatic assembly" by Zhang et al. presents a vision-guided robot system for automatic assembly of mechanical parts. The system employs a SCARA robot equipped with a machine vision system to detect and locate parts, and then perform pick-and-place operations. By using this system, manufacturers can automate their assembly processes, saving time and reducing errors. In "A SCARA robot-based visual servoing system for automatic assembly" by Wang et al., the authors present a visual servoing system that uses a SCARA robot and a machine vision system to perform automatic assembly tasks. The system employs a real-time image processing algorithm to detect and locate parts, and then control the robot to perform the assembly tasks. The system can help to streamline the assembly process, improve accuracy, and reduce costs. "A machine vision system for intelligent robotic assembly" by Gao et al. presents a machine vision system that can be used with a SCARA robot for intelligent robotic assembly. The system uses a real-time image processing algorithm to detect and locate the parts, and then control the robot to perform the assembly tasks. By using this system, manufacturers can automate their assembly processes, improve quality control, and increase efficiency.

"Development of a vision-based robotic assembly system" by Kim and Kim presents a vision-based robotic assembly system that uses a SCARA robot and a machine vision system to perform automatic assembly tasks. The system employs a color-based image processing algorithm to detect and locate the parts, and then control the robot to perform the assembly tasks. By using this system, manufacturers can automate their assembly processes, reduce errors, and increase efficiency. "Robotic visual inspection using a SCARA robot and a machine vision system" by Liu and Guo presents a robotic visual inspection system that uses a SCARA robot and a machine vision system to perform visual inspection tasks. The system employs a real-time image processing algorithm to detect defects in the parts, and then control the robot to perform the inspection tasks. By using this system, manufacturers can automate their inspection processes, improve quality control, and reduce cost.

3. SCARA ROBOT

The Selective Compliance Assembly Robot Arm (SCARA) is widely used in the industry for pick-and-place operations. This report presents a methodology for creating a SCARA robot that picks and places objects based on their size, as determined by a machine vision system. The methodology comprises six steps, starting with object detection using a machine vision system that can determine object size. The robot is then programmed to pick and place objects based on their size, and the gripper is designed to handle objects of various sizes and shapes. The robot is tested in a controlled environment to ensure it can accurately pick and place objects of different sizes. After verification, the robot is integrated into the production line, where the machine vision system provides necessary data to pick and place objects based on their size. Finally, regular maintenance is performed to prevent any potential breakdowns. This methodology is essential in various applications, including logistics and manufacturing, where efficient and accurate pick-and-place operations are crucial. The process pipeline for the robotics part is explained by Figure 1.

A. Selection of Material

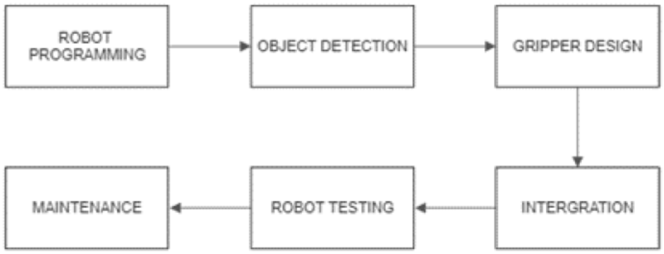

Fig 1. Process pipeline

When it comes to 3D printing, there are a variety of materials available, each with its own unique set of properties, benefits, and drawbacks. These materials include ABS, PLA, PETG, nylon, and polycarbonate, among others. ABS is known for its strength, durability, and heat resistance, but can be challenging to print due to warping and toxic fumes. PLA, on the other hand, is biodegradable, easy to print, and produces minimal toxic fumes, although it is not as strong or heat- resistant as other materials. PETG is a strong and durable material that is also easy to print, but can be prone to stringing and requires a higher printing temperature than PLA. Nylon is a tough and flexible material that is commonly used for parts that require high durability and toughness, but can be challenging to print due to its high melting temperature and tendency to absorb moisture. Polycarbonate is a strong and heat-resistant material that is often used for parts that require high impact resistance, but can be challenging to print due to warping and high printing temperature.

For our project, we decided to use PLA+ material. PLA+ is a modified version of PLA that contains additional materials such as metal powder or carbon fiber, which enhances its properties. It is a popular material due to its ease of use, biodegradability, and ability to produce high-quality prints with a glossy finish. Furthermore, it is stronger and more heat-resistant than standard PLA, making it suitable for our project. To ensure the best possible results, we followed a rigorous material preparation process, including drying and storing the material correctly before printing, to avoid any moisture-related issues.

In addition to proper material preparation, selecting the appropriate printing parameters is critical to achieve the desired print quality and avoid any printing issues. We carefully considered printing temperature, printing speed, layer thickness, bed temperature, and cooling settings for our PLA+ material. Based on our experiments and prior research, we selected the following printing parameters to ensure the best quality prints with the desired mechanical properties: a printing temperature of 215-225°C, a bed temperature of 50-60°C, a printing speed of 30-40 mm/s, a layer thickness of 0.2-0.3 mm, and a fan speed at 50-100% for cooling. We also conducted several test prints to determine the optimal settings for our specific printer and PLA+ material.

B. Design

The robot was designed especially for pick and place operation. The gripper used was a mechanical gripper. This allows the robot to pick and place any type of object. The robot has a total of 4 movements. All of the movements are controlled by different motors. The robot has 1 vertical motion which is facilitated by a lead screw and 3 angular motions. The final degree of freedom is for the gripper. The different views are depicted in Figure 2-5.

Fig 2. Side View

Fig 3. Front View

Fig 4. Isometric View

Fig.5. Top View

C. Machine Vision

The object that is being used as a workpiece is a 100mm circular gauge. We are using a telecentric lens with a collimated back light for accurate dimension measurement. The light from the collimated back light sends photons in a parallel manner such that the image is sharp. This makes the dimension measurement very accurate [3].

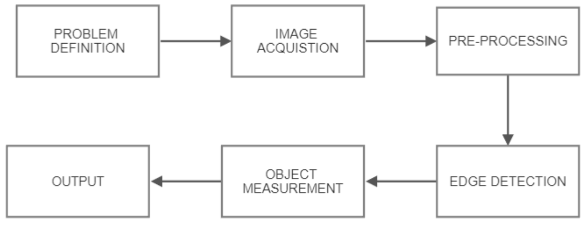

Fig 6. Machine vision process

The telecentric lens negates the effect of change in appearance of the workpiece for different working distances. These conclude the optics of the machine vision part. The process pipeline for the machine vision part is explained by Figure 6. The image processing is as follows:

A. Importing necessary libraries

The entire machine vision algorithm was done using a python notebook in Visual Studio. Before the algorithm, we created a virtual environment and imported the libraries. The libraries needed for this include OpenCV, Numpy and Matplotlib. OpenCV contains several useful functions such as cvtColor, Canny, boundingRect which would be helpful for our image processing. Numpy would be useful for any calculation that we might need in our code. Matplotlib was used to plot the various stages of the processing.

B. Live feed object recognition:

We made use of the VideoCapture function from Open CV. This opens up the camera that is connected to the system. The camera captures the workpiece in frames and send the information to the algorithm. This frame contains the information about the workpiece.

C. Gray scale and Noise reduction:

The frame is then converted to a gray scale image as depicted in Fig 8. This process is commonly called thresholding. All the pixels in the image are converted into black or white pixels. This is done to differentiate between the workpiece and the background. The output of this grayscale image would ideally be workpiece in black pixels and background in white. In order to reduce noise, Gaussian blur is used (Fig 7). This reduces the pixels to expose the noisy pixels. Later, these pixels are removed and a sharper image is displayed.

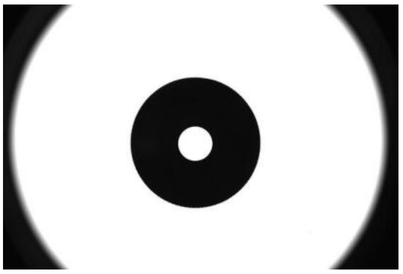

Fig 7. Gaussian blur

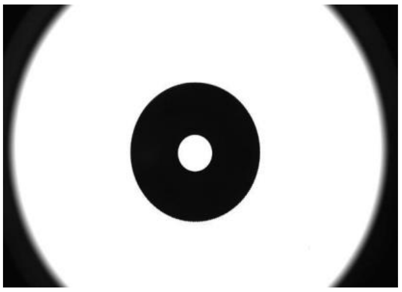

Fig 8. Grayscale

D. Canny edge detection:

Canny gives the edges of the object in the frame. Once these edges are found out, we find the maximum contour. There might be several objects in the field of view. In order to concentrate on one object, we take the object with the maximum contour. After that, we draw a rectangle around the

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 06 | JUNE - 2023 SJIF 2023: 8.176 ISSN: 2582-3930

object by the boundingRect function in OpenCV [4] . This gives us the width and length of the object in pixels, as shown in Fig 9.

Fig 9. Bounding Box

E. Pixels to mm conversion:

The number of pixels can be converted into mm by the following formula:

width = (w * KNOWN_DISTANCE) / FOCAL_LENGTH

height = (h * KNOWN_DISTANCE) / FOCAL_LENGTH

KNOWN_DISTANCE corresponds to the working distance between the lens and the object and FOCAL_LENGTH corresponds to focal length of the telecentric lens. w and h correspond to the width and height in pixels [2].

F. Output:

Finally, the calculated width and height values are displayed on the screen in real time (Fig 10). Along with these values, the circularity of the workpiece is also displayed. This information is sent to the robot and the robot decides to pick and place the object or not. If the values are within the tolerance limit, the robot picks and places the workpiece. From the experiment, we got a deviation of about 200 microns which is considerable for industry standards.

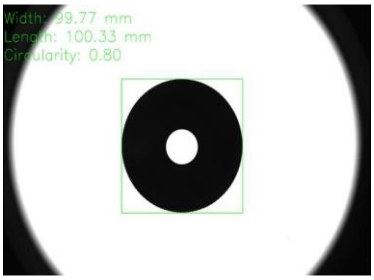

Fig 10. Results

4. ELECTRONICS

Electronics part of this thesis bridges the gap between the robot and the machine vision. The entire robot has an electrical drive system. This means that the robot Is controlled entirely by motors. We used 4 stepper motors and a servo motor for the robot. Everything is controlled using Arduino Uno. The image processing algorithm is done using the Arduino. So, Arduino takes the width and height value from the algorithm and decides to actuate the robot or not. We used homogeneous transformation to decide how much the motors need to rotate to reach the workpiece [7]. The Hardware system consists of various components which are mentioned in table 1.

TABLE 1. HARDWARE ESSENTIAL COMPONENTS

Hardware Components	**Type-Range**
Mind Vision Camera	20MP
Power supply	19V, 6A
Arduino UNO	R3
Motors	Stepper, Servo
Telecentric lens	focal length = 270mm , W.D = 220mm
Jumper wires	As required
Stepper motor drivers	A 4988
CNC shield	Arduino interface

5. CONCLUSIONS

To summarize, the combination of machine vision and robotics has proven to be a highly effective tool for warehouse applications. The presented code illustrates how machine vision can be utilized to accurately evaluate objects in real-time, while the robot makes decisions based on the acquired data. The integration of these technologies can significantly streamline inspection procedures, minimize errors, and enhance efficiency. Automation of inspection processes can help businesses save both time and money while also improving the precision and consistency of inspections. As technology continues to evolve, we can anticipate witnessing even more advanced and sophisticated systems that will push the boundaries of what is achievable with these technologies.

6. REFERENCES

1. "Robotics and Machine Vision Integration" by Adept Technology Inc. - This white paper provides an overview of the benefits of integrating robotics and machine vision in manufacturing and other applications.
2. "Machine Vision and Robotics" by Edmund Optics - This article discusses the role of machine vision in robotics, including object recognition, inspection, and guidance
3. "Robot Vision: Object Recognition, Tracking, and Inspection" by Stefan Florczyk - This book provides an in-depth exploration of the theory and practice of robot vision, with a focus on object recognition, tracking, and inspection.
4. "Robotic Inspection and Quality Control" by Hui Liu and Hong Wang - This research article discusses the use of robotics and machine vision in quality control applications, including defect detection and measurement.
5. "Industrial Robotics: Technology, Programming, and Applications" by Mikell P. Groover - This book provides a comprehensive overview of industrial robotics, including programming, control, and integration with other technologies such as machine vision. 41
6. "Vision-Guided Robotics" by Fanuc America Corporation - This white paper provides an overview of the benefits of vision- guided robotics, including increased productivity, reduced waste, and improved quality control.
7. "Machine Vision and Its Applications in Robotics: A Review" by Jitendra Kumar Rai et al. - This research article provides a comprehensive review of the role of machine vision in robotics, including object recognition, tracking, and inspection.