Integrating Vision System to a Pick and Place Cartesian Robot

K S Tan¹, M N Ayob¹*, H B Hassrizal¹, A H Ismail¹, M S Muhamad Azmi², M S M Hashim², S M Othman¹, A B Shahrman² and Y H Low³

¹ Intelligence Computing and System Informatics Research Group (ICSI), Faculty of Electrical Engineering Technology, Universiti Malaysia Perlis.
² Faculty of Mechanical Engineering Technology, Universiti Malaysia Perlis.
³ BBS Automation Penang Sdn. Bhd.
*nasirayob@unimap.edu.my

Abstract. Vision aided pick and place cartesian robot is a combination of machine vision system and robotic system. They communicate with each other simultaneously to perform object sorting. In this project, machine vision algorithm for object sorting to solve the problem in failure sorting due to imperfection of images edges and different types of colours is proposed. The image is acquired by a camera and followed by image calibration. Pre-processing of image is performed through these methods, which are HSI colour space transformation, Gaussian filter for image filtering, Otsu’s method for image binarization, and Canny edge detection. LabVIEW edge-based geometric matching is selected for template matching. After the vision application analysed the image, electrical signal will send to robotic arm for object sorting if the acquired image is matched with template image. The proposed machine vision algorithm has yielded an accurate template matching score from 800 to 1000 under different disturbances and conditions. This machine vision algorithm provides more customizable parameters for each methods yet improves the accuracy of template matching.

1. Introduction

In this technologically advanced generation, the usage of robotic automation has increased tremendously in industries such as manufacturing, automation, and others [1, 2]. Most of the industries have transformed fixed automation to programmable or flexible automation because either one of them has high adaptability and flexibility in manufacturing and automation process. Vision systems are widely used in industries especially in quality control, object sorting, and product inspection. Vision aided pick and place industrial robot can achieve accurate object sorting with a small error which is 0.1mm under certain disturbances such as lighting, tolerances and angles [3]. However, there are some limitations of vision systems.

Vision aided pick and place cartesian robot performs object sorting through 2D vision but is not able to compute depth of single plane because it relies only on the shape and orientation of the object [4]. The vision system is implemented by prioritizing template matching for object sorting because it can perform matching by comparing object image with template image under different angles and orientations [1]. The vision system will communicate with the cartesian
robot by sending signals through input and output signal modules. Therefore, vision aided pick and place cartesian robot can be deployed through machine vision and cartesian application.

In this paper, machine vision algorithm by using LabVIEW is introduced to solve the imperfection and different colours of object images as they caused failure in object sorting due to unsuccessful in image recognition between object image and template image.

Colour model plays a vital role in image processing as it describes the representation of each colour in term of coordinate system. HSI colour space is selected because separability values from achromatic values are easier to modify and control [5]. The important features of the image can be highly preserved under poor illumination as the extraction of luminance in HSI colour space will not correlate with colour information [6, 7]. In image filtering, Gaussian filter is proposed because the amount of smoothing can be controlled by standard deviation [8]. By performing Gaussian filter on zoomed image, the peak signal to noise ratio (PSNR) increased and mean square error (MSE) decreased yet improved the image’s accuracy [9]. Besides that, image segmentation through thresholding by using Otsu’s method is proposed to identify text information by differentiating the foreground values and background values of the image [10]. The best threshold values are calculated to obtain best separation between classes. For morphological operation, structuring element (SE) is used to interact with image and check whether the shape in image is fitted or missed. Therefore, the characteristics of image is improved by removing imperfection of image in term of noises and unwanted portion [11, 12]. For edge detection technique, Canny edge detection is proposed because it performed optimally in term of edge localization, uniqueness, consistency of response and signal to noise ratio [13, 14]. However, it relied much on customizable parameters and resulted computationally expensive compare to other edge detection methods.

In template matching, geometric matching is chosen as it prioritized low-level features such as curves, edges or high-level features which are made by edges and curves like circle, corners, and rectangles. It performed well on image that contained geometric information regardless of geometric transformation such as rotation, scaling, and disturbances like occlusions, noises, and lightning variation [15]. However, the processing time of geometric matching is longer because it identified the edges and shapes of image. Poor result of geometric matching will be obtained when the textured surface object is used. Despite pattern matching worked smoothly on textured surface object regardless the textures and geometric transformations, poor result is still obtained if pattern matching is performed under object overlapping, non-uniform brightness and object scaling conditions. In short, geometric matching is more relevant compare with pattern matching in vision aided pick and place application because geometric matching can perform efficiently regardless overlapping, lightning issues and scaling issues.
2. Methodology

Figure 1 show the UniMAP Walta Robot with imaging system. For image acquisition process, UniMAP Walta Robot with Logitech C930E business webcam imaging system is constructed in proper environment. Logi Capture software is selected as camera imaging source of NI-IMAQ device. After the image is acquired, the image is calibrated through LabVIEW Vision Assistant. Point coordinates calibration is selected to eliminate perspective error and camera angle distortion yet increased the object matching accuracy. The calibrated image is converted to HSI colour space and Region of Interest (ROI) is created by masking the pixels outside of Region of Interest (ROI). Next, the image is filtered through Gaussian filter and segmented through auto-thresholding by using inter-class variance. Since the binarized image contained some imperfections, fill hole morphological operation is selected to fill up the holes of the image. In addition, Canny edge detection is performed on the binarized image to obtain the edges of object.

After obtaining the edges of object, edge-based geometric matching is performed on the image to obtain high matching accuracy based on edges. Before performing geometric matching, template image is captured and further processed by highlighting unwanted regions. As a result, the accuracy of object sorting will gradually increase as the geometric matching will ignore the highlighted region during matching purpose. On the other hand, there are several parameters that are customized based on conditions. For example, matching score, angles of rotation and others. The matching accuracy depends on the matching score, yet it is set as 800 to obtain a high accuracy matching whereas the angle of rotation is set from 0° to 360°. Once the inspected image and template image are geometrically matched, the object will be sorted based on real-world coordinates through TCP/IP protocol bridging communication between LabVIEW and Python. The overall process in obtaining the coordinates for objects is shown in Figure 2.

![Figure 1. UniMAP Walta Robot with imaging system.](image1)

![Figure 2. Flowchart: Obtaining the coordinates for objects.](image2)
3. Results

In this section, single object sorting result and multiple object sorting result are discussed.

Figure 3 shows several sections of graphical user interface that are designed as simple as possible to ensure it is user friendly and can be operated easily. The first section is importation of templates and files. Before running the application, templates and files are imported by selecting correct templates and files’ locations. Next, single object sorting setting is configured by selecting 1 number of match and 800 for minimum score. Since the camera used is not industrial type camera, therefore the quality of image acquired is not as good as industrial camera. Matching accuracy with a minimal 80% is considered high for current application. There is a 0.5 s delay for this application to prevent constantly overwriting of image data. When the image is geometrically matched, image overlay is shown along with image information. Since the size of image overlay depends on the size of detected object image, this resulted high accuracy of object’s centre coordinates.

![Image of Graphical User Interface](image)

**Figure 3.** Graphical user interface of single object sorting.

Table 1 shows the detected object information after geometrically matched successfully. After comparing the acquired image with template image during geometric matching, the X position is 1155.20 pixels and Y position is 631.31 pixels. The object coordinates are referred from the reference point of work space. The angle is 342.10° while the scale is 99.62%. Since the angle is defined starting from 0° to 360° and not considering scaling option in this application, the matching score is 986.29 which is nearly 100% accuracy. The object coordinates are converted to real-world coordinates in millimeters (mm) and the coordinates are further handled through CSV file. After the object coordinates are updated in CSV file, LabVIEW is communicated with Python through TCP/IP Protocol. Python read the CSV file and further processed the object coordinates by adding the coordinates of robot origin with reference point of work space. Lastly, the final object coordinates that are used for object sorting are calculated and communicated with robot controller over TCP/IP by sending recognized string command for robotic motion.

Table 1

| Object | X Position | Y Position | Angle  | Scale |
|--------|------------|------------|--------|-------|
| First  | 692.00 pixels, 100.03mm | 378.00 pixels, 73.70 mm | 71.00° | 100% |
| Second | 1321.80 pixels, 224.23 mm | 408.10 pixels, 80.24 |

Figure 4 clearly shows the results of multiple image overlays and image data after geometrically matched.

In table 2, the first object detected is on the left as the position is closed to the reference point while the second object detected in on the right. The result of first object is X position 692.00 pixels, 100.03 mm, Y position 378.00 pixels, 73.70 mm, angle 71.00°, and scale 100% whereas second object is X position 1321.80 pixels, 224.23 mm, Y position 408.10 pixels, 80.24
Table 1. Single object image data processing and real-world conversion result.

| match number | X position (pixels) | X position (mm) | Y position (pixels) | Y position (mm) | Angle (°) | Scale (%) | Score   |
|--------------|---------------------|-----------------|--------------------|-----------------|-----------|-----------|---------|
| 0            | 1155.2              | 191.13          | 631.31             | 124.32          | 342.10    | 99.62     | 986.29  |

Figure 4. Graphical user interface of multiple objects sorting.

mm, angle 204.72°, and scale 100.39%. The matching score for both objects are 932.70 and 992.60 respectively. The matching accuracy are high because the matching scores are more than 80% in term of percentage. For multiple objects sorting, sequential command are sent to the controller in the acceptable time interval. In order to avoid conflict during object sorting, the string commands are read from left to right.

Table 2. Multiple objects image data processing and real-world conversion result.

| match number | X position (pixels) | X position (mm) | Y position (pixels) | Y position (mm) | Angle (°) | Scale (%) | Score   |
|--------------|---------------------|-----------------|--------------------|-----------------|-----------|-----------|---------|
| 0            | 692.00              | 100.03          | 378.00             | 73.70           | 71.00     | 100.00    | 932.70  |
| 1            | 1321.80             | 224.23          | 408.10             | 80.24           | 204.72    | 100.39    | 992.60  |
4. Conclusions and Future Recommendations

In a nutshell, implementation of machine vision technology and NI vision tools in vision aided object sorting is accomplished easily through LabVIEW. The machine vision algorithm used consists of HSI colour model, Gaussian filter, optimum global thresholding by using Otsu’s method, filling hole morphological operation, Canny edge detection and edge-based geometric matching. The respective LabVIEW machine vision algorithm is integrated successfully with python programmed UniMAP Walta Robot through TCP/IP protocol. Lastly, theoretical test run and evaluation of complete system’s performance is carried on successfully through string command ‘[@MOVE P, X-coordinates Y-coordinates 0.0\r]’ for object sorting.

For future work, 3D machine vision can be implemented into current system to improve the accuracy, processing speed and others. By using 3D machine vision, the current state of object such as lying down, hanging or upright can be visualized and further processed. It has more independency and flexibility compare to 2D machine vision. Besides that, the current work space can be integrated with vibratory work space to obtain correct object’s orientation by gently shaking the work space when dealing with complex object’s orientation. In short, the future integration improves the capability of object sorting.

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