Study of Machine Vision System for Automated Pineapple's Eyes Detection

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***Abstract*— This study aimed to improve the production process of canned pineapple by introducing an algorithm that utilizes machine vision and image processing techniques to detect and locate pineapple eyes accurately after the peeling process. The result can be subsequently transmitted the coordinates to the automatic pineapple eyes removal machine. The algorithm's primary objective is to improve productivity, especially by reducing waste due to human error. Therefore, the prototype has been made. Including the image acquisition process and the rotating system to capture pineapple surface features, the system was operated by a stepper motor along with an inspection camera for data collection. The algorithm was created based on thresholding method, with the calibration, pineapple eyes can be located in term of position(x) and angle (φ) of rotation axis. In summary, from our design and experiment. Our algorithm results in a maximum error of position (x) at 4.871 mm and a maximum error of angle (φ) at 3.415 degree at the processing time of 0.68 millisecond, with the entire process taking 20.92 seconds.**

Keywords*— *pineapple's eyes Detection, Machine Vision, Canned pineapple production

I. Introduction

Numerous technological and methodological advancements have been made recently to increase the value of agricultural products. To increase efficiency and reduce costs, machinery and automation have been integrated into the production process. The usage of automation can be seen since agricultural production is an important and essential food source of human. Furthermore, the overwhelmingly rapid growth of the population put pressure on the agricultural sector to produce in more quantity with limited labor resources. Consequently, incorporating advanced technologies such as robotics and automation into production processes becomes necessary to enhance productivity, efficiency, and sustainability to meet the escalating demands for food [1].

Accordingly, our objective is to design and develop the classification algorithm for specifically inspect and located the position of pineapple eyes, since pineapple is one of the economically valuable products. Nevertheless, the preparation of pineapples involves a more complex peeling process compared to other fruits, as it requires the removal of "eyes" embedded within its skin. These eyes must be eliminated to ensure the fruit quality, appearance, and safety for consumption. Currently, the conventional method of removing pineapple eyes involves manually cutting using a specialized knife. While this traditional approach allows for precise eye removal, it can be time-consuming, labor-intensive, and prone to human error, potentially affecting the quality of the final product. Consequently, this study is exploring more efficient and automated alternatives to enhance the canned-pineapple productivity by using machine vision.

The machine vision system is capable of capturing high-resolution images of pineapples surface using a specialized cameras equipped with appropriate lighting [2]. The rotation system is designed for taking multiple images at different angles to ensure complete coverage of the pineapple surface. To prepare the images for further analysis, image pre-processing is needed. Noise reduction, image resizing, and color space conversion, these steps enhance the image quality and ensure that the subsequent processing stages operate effectively. In order to differentiate the eyes from the surrounding pineapple surface, image thresholding techniques are employed. By using pixels value intensity, the system can identify distinct regions corresponding to the eyes and the pineapple surface. After thresholding, the system segments the image into distinct regions and analyzes them to identify and isolate the pineapple eyes. Morphological operations, such as erosion and dilation, may be applied to refine the segmentation results and improve the accuracy of the detection process. Once the pineapple eyes are detected, the position can be defined by converting the pixel position in to an angle of rotation and distance from the origin by calibration.

This paper is organized as follows. In section 2, the design of the system for image acquisition is described. The architecture of the algorithm is demonstrated in section 3, including feature of captured data and classification process. In section 4, the outcome and the efficiency of the system are examined. In last section we concluded the study and outlined potential future research.

II. DESIGN OF ROTATION SYSTEM

The foundational idea of the image acquisition system revolved around the shape of a pineapple, since after the peeling process the appearance of the pineapple can be considered cylindrical, as shown in Fig. 1.

The overall system is designed as a cylindrical rotating system to ensures that the entire surface of the pineapple is visible to the machine vision system. The position of the pineapple eyes can be determined by the coordinate system is defined by two values, the distance along the rotation axis (x) and the angle of rotation (φ).

Fig. 1 pineapple after peeling used as data for experiment

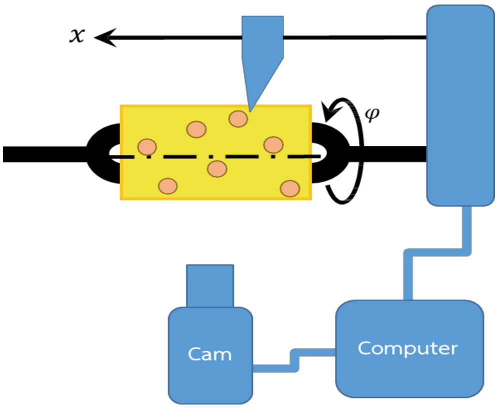

Fig. 2 Conceptual design of machine vision system.

The camera configuration is significant in machine vision systems to achieve the desired result. In general, inspection cameras are classified into two types: area scan cameras and line scan cameras. Both camera types have their advantages. Area scan cameras capture an image of an entire scene in a single frame. This means it offers a broader field of view, which is particularly advantageous when inspecting three-dimensional objects with complex surfaces, providing a comprehensive field of view. On the other hand, line scan cameras capture image one line at a time, building up a larger image as the object moves past the camera's field of view. This type of camera is typically used for continuous processes or when extremely high-resolution images are required. Therefore, in this project, a 2.3-megapixel area scan camera has been chosen due to its benefits to capture the detailed features of a pineapple, eyes and skin texture. It provides comprehensive coverage of the pineapple's surface in a single frame, facilitating efficient inspection and accurate enough for image analysis. Along with a proper light source, a panel light is chosen to minimize shadows, glare, and reflections on the pineapple's surface, which can negatively affect the detection process.

In the design workflow, the pineapple is first mounted onto the rigid platform, ensuring stability during rotation. The motor and gear system initiates the rotation at a predetermined angular velocity, providing an inclusive view of the pineapple's surface to the machine vision system.

Considering the significance of an accurate rotational angle, stepping motor is used because of its ability to rotate in discrete steps accurately, with the rotation angle being determined by the number of steps per revolution.

Therefore, the prototype of the machine vision system is created, containing the function to mount and rotate the pineapple and machine vision system with the proper length for display.

III. CLASSIFICATION ALGORITHM WITH IMAGE AQUSITION

A. Images acquisition system

The system consists of 4 parts, camera, lightning, pineapple holder with a positioning system and outer frame that support the camera. The overall design is shown in Fig.4.

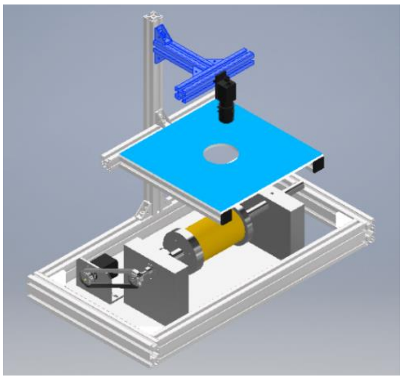

Fig. 3 Machine vision system for pineapple inspection

After inserting a pineapple into the machine, the camera will take a photo. The motor will rotate the pineapple by some degrees and then the camera will take another image. This repeats until the whole surface is covered. The lighting panel intensity can be controlled by external power supply. The pineapple holder that is connected to a stepping motor controlled by Arduino UNO to rotate the pineapple. Together with a main computer, this allows the images to be taken immediately after each rotation. With this design, the camera position can be adjusted as needed. The pineapple can be swapped out without affecting the position of the rest of the system.

B. Image preprocessing

Before processing, all images taken from a pineapple will be merged in to a single, elongated image. This image represents the outer surface of a cylinder which is an ideal model of a pineapple. Depending on the required precision, each image can be further/closer angle apart as needed [3]. Each image will be crop accordingly to the total number of images taken. The pixel location of the merged image can be accurately mapped to the actual position in terms of distance (x) and rotation angle (φ). The Fig.4 and 5 depict a merged image created from multiple images.

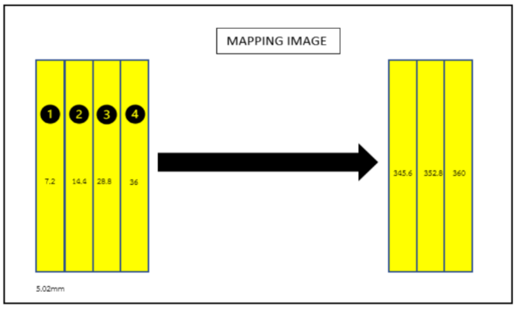

Fig. 4 conceptual of merging image map

Fig. 5 Each image strip combined into a single image.

The preprocess can also be improved with the use of HSV. HSV (hue, saturation, value) color space is a color space that represents colors differently from some color spaces like RGB. In RGB, pixels that are close to each other and typically perceived as having similar colors can have very different values in RGB color space. Since all 3 values in RGB represents colors. Processing colors based on RGB values directly can be difficult, so alternative suitable representations like HSV can be used. Instead of representing values of 3 colors, only hue (H) in HSV will represents color. We then can use this color to process colors in situations where lighting is not constant. In the example below, three yellow images are shown in Fig 6. While the RGB values from all of them are very different, the hue values in HSV are the same. This is because these three images are darked/brighten versions of each other. This will be beneficial for processes like color masking to detect some objects in an image based purely on color.

Fig 6. Three yellow boxes sample

C. *Image processing algorithm*

The overall process consists of 4 main parts, which are, separation of possible pineapple eye regions, faulty regions removal, recognizing those regions as objects, and determining object's location.

In order to detect pineapple eyes, we need to separate them from fruit content, we also need to remove any unwanted parts from the process, so we must do some noise reduction. We then need to find the locations so we can cut them. We then turn groups of pixels that are eyes into objects so we can easily measure their properties. Overall processes are concluded into flowchart in Fig 7.

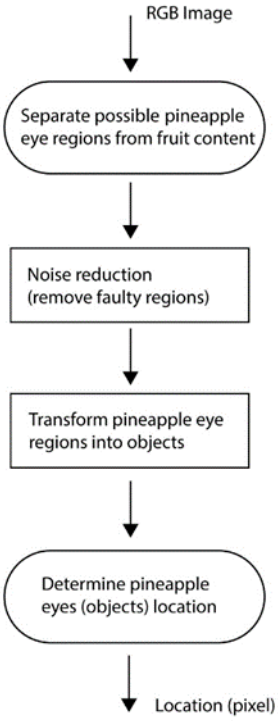

Fig. 7 Image processing flowchart

With proper lighting condition, the first part can be done with image thresholding. This is a process where pixels in an image get separated into 2 groups, the first group contains all pixels which have value under the threshold value, another one contains the rest. The exact threshold value can be determined by testing with the actual lighting condition. Since pineapple eyes are significantly darker than the fruit content. We can separate them by thresholding the grayscale version of the original image. As shown in the Fig 8.

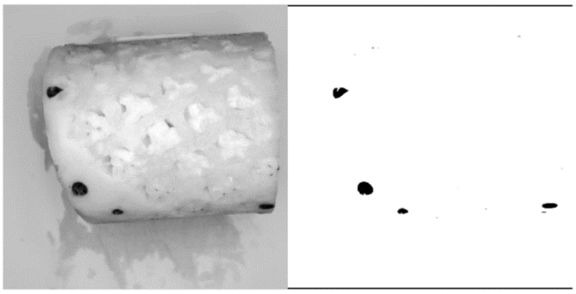

Fig. 8 Image thresholding to spot pineapple eyes.

After thresholding, some parts that got detected might be faulty. By using morphological operations, which are image operations based on shape, some shapes will enlarge or disappear from the image. In this case, by using erosion (The output pixel is the minimum value of neighbor pixels, small clumps of pixels will be erased. Lines will be thinned) and dilation (The output pixel is the maximum value of neighbor pixels, small clumps of pixels will become larger, Lines will be thickened). We can try to erase small clumps of pixels which mostly are noises from the previous process with erosion, then we can enlarge the pixels clumps left from erosion by dilation so that the actual size of detected eyes is preserved.

The black regions now represent the pineapple eyes we want to detect [4]. We then convert groups of connected black pixels into objects by using connected-components labeling. This is a process where a group of nearby pixels are recognized as the same object. Pixels are joined together if they are next to each other and have the same value. The whole image will be sectioned into objects which can represent pineapple eyes as shown in Fig.9. In this step, only large enough objects will be kept for processing as another method of faulty region removal.

The final step is to calculate the positional data of the object. By drawing rectangular bounding box, then the centroid of the bounding box is used as the centroid of the object and the representative position of the object [5].

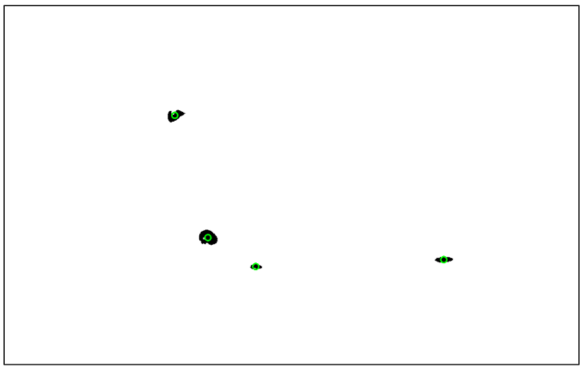

Fig. 9 Connected component analysis to specify the position of pineapple eyes.

The final result that mapped the actual image of the pineapple is shown in Fig. 11 and the flowchart of the image processing processes is presented in Fig. 10.

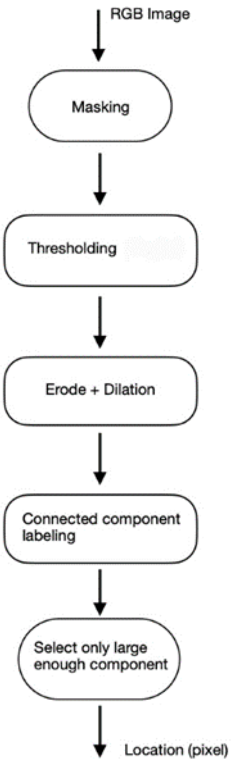

Fig. 10 Determine Pineapple Eye location process flowchart.

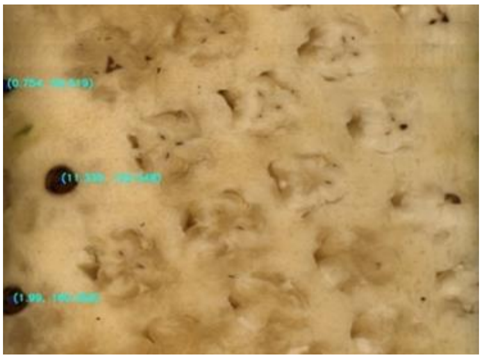

Fig. 11 Example result.

D. Positions postprocessing

Since the sent positions will be used as positions to remove a certain amount of fruit content, Once the image has been processed, if the area of any given object is too large, we need to segment that object into smaller objects to accommodate the actual tool size. In this work, we simply draw a bounding box over the object, then splitting it into smaller squares, each square centroid will now represent the actual positions that the tool can remove. The sample image of the process is shown in Fig. 12

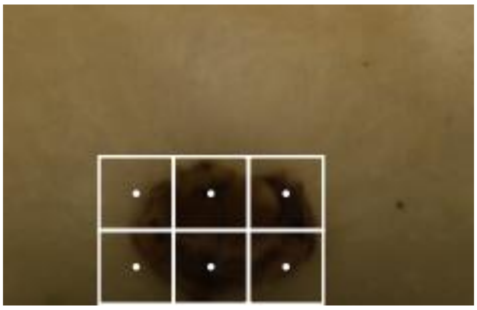

Fig. 12 Sample image of the process.

Once we get actual positions, we can rearrange them so that the removal tool will have to cover the possible shortest distance. To solve this, all positions can be represented as a dense graph, where the distance between each node is also the weight of that node. The problem is similar to the travelling salesman problem, which can be solved with algorithms such as Christofides algorithm [6] or simulated annealing. Nevertheless, finding the exact solution for this problem might be time-consuming for this application. The optimal algorithm for a task depends on several factors.

IV. ALGORITHM PERFORMANCE EXPERIMENTS AND RESULT

Two experiments were conducted for the system. The first one is using an artificial pineapple to test the accuracy and precision of detected locations; the other is using real pineapples to test detection results. Both experiments will be performed three times for each subject consecutively.

In the first experiment, the artificial pineapple is used. It is a 3D-printed plastic cylinder. The outside of the pineapple is covered with a paper with markers acting as pineapple eyes on it. The marker templates were designed with graphic software and the papers were printed with 1:1 scale. With this method, the locations of markers/pineapple eyes can be accurately determined within the software. Marker patterns were created in several variations including size and edge clarity. The second experiment is performed by using actual pineapples, we measure the locations on each eye then compared to the result from the system. This test is to verify the robustness of our system when facing actual subject. The inspection object sample are shown in Fig 13 and 14.

Fig. 13 Printed papers with markers.

Fig. 14 actual pineapple for tested.

The result of the experiment will be in the same format as shown in table 1. (x and φ refer to each subject)

Table 1, The efficiency testing table layout

Position (x, φ) (millimeters, degree)		
reference	x_{ref}	φ_{ref}
1st measurement	x_1	φ_1
⋮	⋮	⋮
nth measurement	x_n	φ_n
MAE	$\frac{1}{n}\sum\lvert x_i - x_{ref}\rvert$	$\frac{1}{n}\sum\lvert \varphi_i - \varphi_{ref}\rvert$

One of the results from the experiment with the printed marker and one of the results from the experiment with real pineapples are shown in table 2 and table 3, respectively.

Table 2: result of the experiment with the printed marker

	Position (x, φ) (millimeters, degree)						
Ref	(19.23, 55.66)	(105.28, 78.54)	(96.20, 162.66)	(33.96, 204.35)	(74.,00, 241.83)	(121.42, 290.42)	(24.35, 321.42)
1st	(18.80, 56.88)	(105.43, 80.15)	(96.02, 164.12)	(33.18, 205.84)	(73.59, 243.23)	(121.76, 290.00)	(23.77, 322.44)
2nd	(18.82, 56.97)	(105.44, 80.18)	(96.03, 164.25)	(33.19, 206.19)	(73.60, 243.42)	(121.78, 290.00)	(23.77, 322.63)
3rd	(18.82, 56.95)	(105.45, 80.23)	(96.03, 164.16)	(33.18, 205.95)	(73.58, 243.27)	(121.75, 290.00)	(23.76, 322.58)
MAE	(0.42, 1.28)	(0.16, 1.64)	(0.17, 1.52)	(0.78, 1.64)	(0.42, 1.47)	(0.35, 0.42)	(0.59, 1.13)

Table 3: result of the experiment with real pineapples.

	Position (x, φ) (millimeters, degree)		
ref	(7.26, 184.03)	(2.30, 242.16)	(40.95, 253.65)
1st	(7.52, 184.10)	(2.47, 241.93)	(40.11, 253.54)
2nd	(6.95, 183.73)	(2.27, 241.97)	(40.01, 253.52
3rd	(6.98, 183.70)	(2.32, 242.13)	(40.14, 253.59)
MAE	(0.11, 0.19)	(0.05, 0.15)	(0.86, 0.10)

The results of the first experiment indicate a maximum position (x) error of 2.66 millimeters and a maximum angular rotation (φ) error of 1.64 degrees. Similarly, in the second experiment involving real pineapples, the maximum position error (x) was found to be 4.87 mm, and the maximum angle error (φ) was observed to be 3.42 degrees.

The processing time of the image processing algorithm is tested using timeit function within python library (the algorithm was implemented in python language) and the result of 10000 times average is 0.6814 ms on a laptop with following specification.

- CPU: Ryzen 5600H
- RAM: 16 GB at 3200 MHz (DDR4)

The overall results are all within the requirements. The system produces a satisfactory result and also suitable to be used in a production environment.

V. CONCLUSION AND SUGGESTION

In this study, we have developed a prototype machine vision system that accurately detects pineapple eyes and sends positional data to the automated pineapple removal process. This system aims to reduce human error and improve overall efficiency in the pineapple processing industry. The model of mounting and rotating have been designed and developed for image acquisition process to retrieve the complete coverage of the whole pineapple surface. The detection algorithm has been created for the machine vision system to accurately identify and differentiate pineapple eyes from the surrounding surface. By applying the methods of thresholding and morphology, the position of each pineapple eye can be defined in the form of pixel location. After calibration, we can calculate the actual position in terms of distance (x) and degree of rotation (φ).

The prototype has been tested and examined for its performance, and the results show promising potential for its accuracy in detection of pineapple eye on the surface of a pineapple. Maximum errors from the calculated positional data are 4.871 millimeters in position (x) and at 3.415 degrees of rotation (φ). The computation and image acquisition duration can be improved by using higher specifications of computers and cameras.

For further development and utilization, the rotational speed can be increased to reduce the duration of the image acquisition process. Beware that the mount and rotation system needs to be stable to precisely determine the position and avoid errors in the process. The image processing algorithm can also be implemented on a lower class of device while still achieve reasonable processing time with more optimized code. A single board PC would be sufficient for both computation of the algorithm and controlling the stepper motor. Since the study worked with pineapple eyes which are apparently distinct from the surface. The designed algorithm in this work is fairly simple, resulting in low computation while still obtaining reasonable accuracy. If a similar technique is used on other types of fruit that the unwanted parts are harder to differentiate. Additional methods of differentiation and noise removal may be needed. One may forego the traditional methods like the one in this paper and opt to use more advanced method like machine learning with better hardware to accommodate it to achieve results within a reasonable time. The convolutional neural network could be the choice, however more pineapple images and the labelling may be needed as a dataset.

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