THE IMAGE PROCESSING IN A VISION SYSTEM-BASED SIZE INSPECTION FOR DRIED FLATTENED BANANAS

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ABSTRACT

The bananas are an economically significant fruit in Thailand, both for domestic consumption and export. Thailand has opportunities to further expand the value of exports. This includes the development of various banana products, especially dried bananas, which is a method of transforming regular bananas into higher-value products. In the distribution of dried flattened bananas, they are sorted into two groups: small and large sizes. Currently, the size sorting of dried flattened bananas is done manually. The human-based size sorting varies among individuals due to the lack of standardized criteria for distinguishing small and large sizes. Furthermore, this manual process can lead to fatigue, especially when working for extended periods of time. For this reason, the aim of this research is to develop an automated system for automatically sorting the sizes of dried flattened bananas using a vision system with LabVIEW software. The criteria for size sorting are as follows: large-sized bananas must have a length greater than 77 mm, and the surface area captured by the low-cost web camera must be no less than 2780 mm². Based on the experimental results, the sorting was divided into three categories: detecting only small-sized dried bananas, detecting only large-sized ones, each with a quantity of 50 pieces, and detecting a mixture of small and large sizes, with a total quantity of 50 pieces (25 of each size). The accuracy of the program for detecting small-sized dried bananas, large-sized ones, and the mixed sizes was found to be 96.00%, 94.00%, and 94.00%, respectively.

KEYWORDS: Dried flattened bananas, Drying bananas, Images processing, Inspection, Vision system

1. Introduction

Bananas are one of the most important agricultures in world trade [1]. In addition, bananas are one of the industries' products that significantly contribute to the economy of Thailand and are popularly used in various food processing and culinary applications. The preservation of bananas for future consumption is also in demand, particularly dried bananas. In the process of drying bananas, ripe bananas are peeled and sun-dried until they achieve the desired color and texture that meets the quality standards set by businesses. Subsequently, these dried bananas are compressed to become flat for distribution. The bananas are sorted and divided into two sizes after compression: large and small, through human observation. Evaluating objects through human visual observation is a process that is greatly influenced by personal judgment, monotonous, requires a significant amount of time, and demands considerable effort [2-4].

In order to enhance both the productivity and quality of food production, it's imperative to create proficient and innovative methods for detecting food processing [5]. An intriguing alternative involves the application of computerized image analysis techniques, often referred to as computer vision systems. These techniques effectively address the shortcomings of visual and instrumental methods, offering an objective way to measure color and other physical factors. [2, 6, 7]. Fundamentally, the vision system is made up of standard sources of illumination, a digital or video camera employed to capture images, and computer software specifically designed for the analysis of these images. [8-11]. However, the fact that there is a difference in the intensity of pixel brightness, leading to a change in the count of pixels with different characteristics, will reduce the precision of the measurement. [12]

Applications of computer vision systems encompass tasks like categorization, size determination, defect detection, and quality assessment across various sectors, including the food and fruit industry. In the pursuit of quality monitoring, this effort significantly aids researchers and industry professionals, thereby contributing substantially to the enhancement of inspection efficiency such as apple, carrot, fish, banana, soybean etc. [1, 13-19]

The aim of this research is to classify the sizes of dried bananas into small and large sizes, with the intention of reducing the reliance on manual labor and establish standardized sorting procedures using low cost web-camera. The criteria for this sorting process include evaluating both the [1] length and [2] surface area of the dried bananas, which is achieved using a vision system integrated through the LabVIEW software.

2. Material and method

The separation of dried bananas into large and small sizes employs two criteria: length and area. The length is measured from both borders of the dried banana, and the area is calculated by counting the number of pixels in the image captured by the camera. Subsequently, image analysis is conducted using a vision system. Prior to the image analysis, there are preparatory steps aimed at reducing noise and unnecessary elements from the image, in order to facilitate a rapid and highly accurate analysis. The preliminary steps before image analysis include: 1) Image acquisition, 2) Pre-processing, 3) Processing, and 4) Post-processing. Following these steps, the image is then subjected to analysis to present the results."

The prototype for inspecting dried flattened bananas was designed based on the use of a food-grade conveyor belt for food products, with web camera detection.

2.1 Image acquisition

In this research, a web camera was utilized as the detection camera due to its affordability and suitability for use in small-scale factories. The camera has a resolution of 1280 x 720 pixels and connects to a computer via a USB port. The vision system's critical control factor is the interaction between ambient light and objects. Light is the most crucial element in obtaining high-quality images, as variations in light intensity significantly impact the results of the image analysis program by altering pixel values. Consequently, a covering has been implemented to shield the object and the camera from uncontrollable external light sources, such as light bulbs or sunlight, which might affect the object. Instead, a controllable light source, namely a bar light, is employed, as depicted in Figure 1 The image acquisition from the web camera while the conveyor belt is in motion results in a colored image, as shown in Figure 2. However, the obtained image is blurry because of capturing photos during movement, and the affordability of the web camera results in a slower shutter speed. The maximum speed of the conveyor belt was 35 cm per second, which prevented the error from burring. As a result, while feeding dried bananas onto the conveyor belt, it's essential to position them in a direction that is perpendicular with the motion path. This is done to counteract the blurriness in the image that matches the motion direction, thus enabling accurate length measurements.

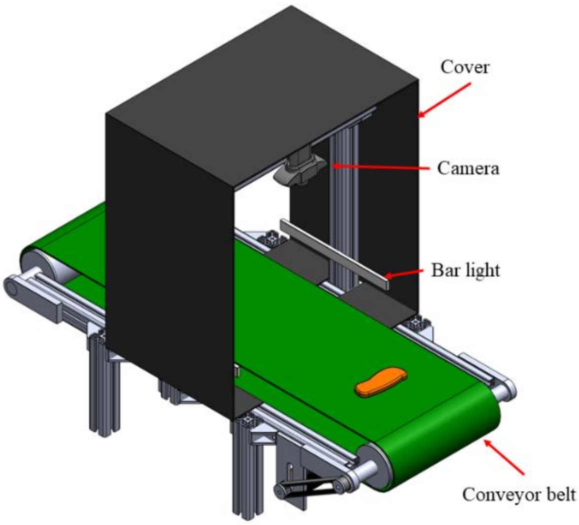

Figure 1 The size-sorting inspection mechanism for dried bananas and the positioning direction of the dried bananas in correspondence with the motion

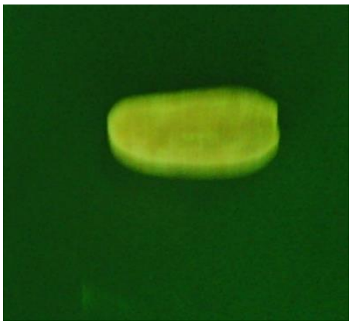

Figure 2 The image obtained from the web camera while the conveyor belt is in motion

2.2 Pre-processing

After acquiring the images, the next procedure involves preprocessing the images before performing any analysis. This stage involves eliminating unnecessary image data, which helps in accelerating the image analysis process by reducing the computational workload. The computation time is influenced by the pixel quantity, and having extra uninformative pixels can lower result accuracy. Therefore, in various scenarios, specific region of interest (ROIs) are isolated. This involves extracting ROIs from individual images using masks that cover either the whole image or a chosen section.

The data values of the images obtained from the camera by the program are represented as pixel values. Therefore, it becomes essential to transform them into real values to facilitate the measurement of length and area for the dried banana. In the process of image conversion, a grid is utilized to enable the program to compute the distance between two points along both the horizontal and vertical axes, using pixels as the unit of measurement. Subsequently, these values are converted into millimeters.

Prior to analyzing the image, it's essential to remove any interference signals (noise) or unnecessary image data. This is achieved by converting the image into a grayscale format, as the image obtained from the camera is in RGB. The fundamental idea is accomplished through the creation of a weighted total involving the R, G, and B components.

$$Y = 0.3R + 0.59G + 0.11B \tag{1}$$

where Y is pixel value of the gray scale image, R, G, B are three primary colors red, green and blue, respectively

After converting the image into grayscale, in order to eliminate these noisy regions and small pixel areas (i.e. undesired pixels), morphological opening (erosion followed by dilation) and closing (dilation followed by erosion) operations were employed. The determination of the projected area for each identified object was achieved through a process of counting the pixels situated within the boundary of the object within a binary image. This process defines the threshold value, enabling the partitioning of the source image. Pixels with values equal to or exceeding the threshold are recognized as pertinent to the object (illustrated as white pixels), while pixels with values lower than the threshold are recognized as pertaining to the background (depicted as black pixels), The purpose is to separate whole target regions from the surrounding background. As shown in Figure 3.

Figure 3 Binary image

2.3 Processing

This step involves processing to identify the border of the dried banana for the purpose of measuring its length. The boundaries of the dried banana are detected by initiating from the two sides of the image frames and advancing towards the central region. Two vectors of two sides of the image are moved to the center of the image. Borders are distinguished through the analysis of changes in pixel intensity gradients. The computation entails measuring the absolute difference between a pixel's intensity and its preceding counterpart. When the absolute value of the current pixel significantly diverges from the previous stage, it is recognized as an edge pixel. As shown in Figure 4. Typically, borders can be extracted from grayscale or binary images. However, since we look for the border after converting it into a binary image, it becomes easier to find the border due to the clear changes in pixel values during the search along the edge. Specifically, the background, which has pixel value 0, is distinct from the dried banana object, which has a value of 1 As shown in Figure 5, showing the border value is 1.

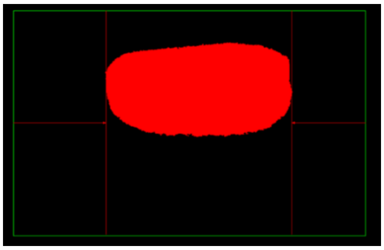

Figure 4 Searching the area of the border (green frame) and the boundary found (red vector)

Figure 5 Histogram of boundary

2.4 Post-processing

In post-processing, which is the final step before image analysis, this stage requires preparing the image to be as clear and complete as possible prior to interpreting the image results to prevent erroneous outcomes during analysis. This involves managing image data by segregating the image background from the object. This is necessary due to the varied light sources that may affect the dried banana, potentially distorting pixel values and affecting the conversion to a binary image, which could result in gaps within the dried banana. Therefore, the utilization of the 'Fill Holes' morphological operation is necessary. This operation ensures that objects are completely enclosed, leaving no gaps or interruptions within their boundaries and having no impact on the border as shown in Figure 6.

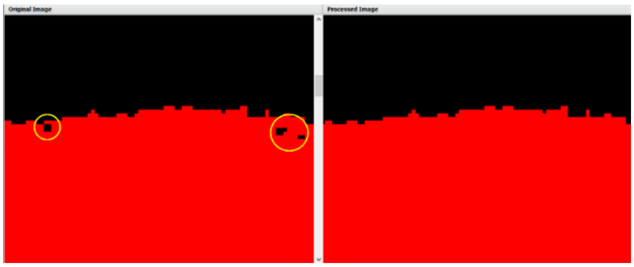

Figure 6 The image from the fill hole function

2.5 Analysis

This constitutes the procedure for interpreting the outcomes extracted from images acquired through the camera. These images have undergone enhancements to yield outcomes of the highest accuracy and precision. In the subsequent image processing step, there is a conversion of units from pixels to real measurements in millimeters by the rule of three 5.713 pixel are 1 mm. This conversion enables the presentation of the actual length measurement of the dried banana. Furthermore, by identifying the initial and concluding boundaries, both distances, which represent the length measurement of the dried banana, are determined. In the area-determination phase, the process involves the computation of an area obtained through the transformation of an RGB image into a binary image. This is executed by tallying the overall pixel count within the binary image and subsequently converting the result into real-world units, specifically in terms of millimeters squared.

2.6 Criteria for selecting the size of dried banana

In this research, a classification has been established for dried bananas, encompassing two distinct categories: those of modest dimensions classified as "small," and those of more substantial dimensions categorized as "large." The criteria dictating this classification are rooted in both the length and the surface area of the dried bananas. This classification criterion draws from the dimensions of the smallest dried banana among those categorized as larger specimens, essentially serving as the standard for identifying the attributes of 'large' dried bananas. For a dried banana to meet the criteria of being categorized as 'large' in size, it must have a minimum length of 77 mm. This measurement is conducted using a ruler to ensure consistency and accuracy. as shown in Figure 7. For the area of the dried banana, Estimating or determining the area of bananas presents difficulties due to its non-geometric and non-uniform characteristics. Additionally, the lack of uniformity among each piece. Nonetheless, a criterion for selecting the banana size can be established by using the largest banana within the small-size banana group as a reference. This can be achieved by measuring the area using a vision system. Subsequently, the area of this reference banana becomes the benchmark for determining the sizes of all bananas. In other words, if the area of other bananas, which are measured using the vision system, is smaller than the benchmark, they are considered small bananas. Similarly, if the measured area is larger than the benchmark, the respective banana is classified as large. The vision system indicates that the minimum area for a dried banana to be classified as 'large' should not be less than 2780 mm^2. as delineated by the equations formulated.

$$\text{Size} = \begin{cases} \text{Large, if Length} \geq 77\text{mm and Area} \geq 2780\text{mm}^2 \\ \text{Small, otherwise} \end{cases} \tag{2}$$

The determination of a dried banana being classified as 'large' in size, it's essential for both its length and area measurements to exceed a predefined threshold.

Figure 7 Measure the dried banana length with a ruler.

3. Result and discussion

3.1 Length and area detection

The examination of dimensions calculated from the program, divided into examinations of length measurement and the measurable area size, with criteria for large-sized dried bananas. The measured length must be greater than 77 mm, and the binary image area must exceed 2780 mm^2. This involves measuring the size of 15 pieces of dried banana, with each piece being measured three times, then calculating the average length for comparison with the actual measured length obtained using a ruler, in order to determine the error value. However, for the area, direct calculation of the true area isn't feasible due to the banana's non-geometric shape, which complicates precise computation. Therefore, the calculation must be solely carried out through the vision system.

We've divided the size examination into two phases. In the first phases, when examining small-sized dried bananas, the maximum and minimum differences between the average length and the actual measured length are 4.98% and 1.68%, respectively, as shown in Figure 8a. In the second examination phases, when inspecting larger-sized dried bananas, the maximum and minimum differences between the average length and the actual measured length are 2.94% and 0.30%, respectively, as shown in Figure 8b. The margin of error in measuring the length of dried bananas, both small and large, using a vision system compared to actual measurements does not exceed 5%, allowing for reliable length measurements. Concerning the area calculations for dried bananas through the vision system, there are noticeable differences even for repeated measurements of the same piece, as shown in table 1 for small sizes and table 2 for large sizes, primarily due to external lighting conditions and the camera's relatively slow shutter speed [20]. However, since a minimum area threshold has been defined, this variation doesn't significantly affect the interpretation of the dried banana's area size.

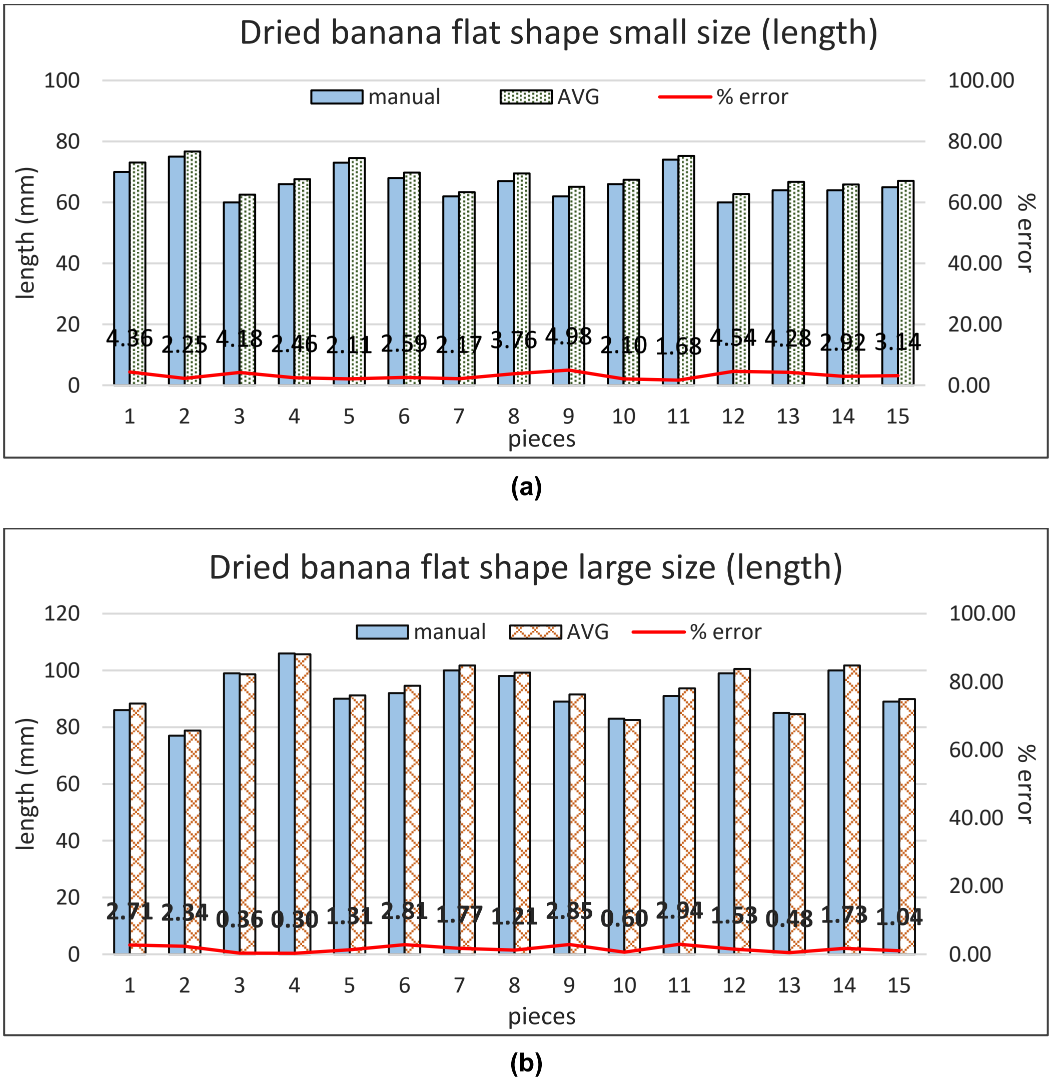

Figure 8 The results from examining the length values of 15 pieces of dried banana, each measured three times (a) For the smaller-sized dried bananas, (b) For the larger-sized dried bananas.

Table1 **The area measurements for small sizes**

Pieces	Area (mm^2)				
	1	2	3	average	SD
1	2745.49	2566.46	2548.98	2620.31	108.76
2	2519.65	2650.82	2771.11	2647.19	125.77
3	2313.31	2075.46	2182.07	2190.28	119.14
4	2234.65	2278.73	1965.13	2159.50	169.77
5	2480.74	2531.59	2176.42	2396.25	192.07
6	2222.66	2425.82	2232.07	2293.52	114.67
7	1848.14	1919.6	2006.22	1924.65	79.16
8	2230.27	2311.02	2216.02	2252.44	51.23
9	2185.97	2193.42	2269.09	2216.16	45.99
10	2297.53	2188.77	2278.73	2255.01	58.13
11	2576.68	2499.2	2584.93	2553.60	47.29
12	2152.83	2121	2081.28	2118.37	35.85
13	2370.75	2230.76	2241.26	2280.92	77.97
14	2239.64	2312.5	2232.27	2261.47	44.35
15	2346.21	2410.21	2254.99	2337.14	78.01

Table2 **The area measurements for large sizes**

Pieces	Area (mm^2)				
	1	2	3	average	SD
1	3213.89	3289.6	3214.74	3239.41	43.47
2	2906.07	2942.42	3008.07	2952.19	51.70
3	3978.31	4013.81	4018.96	4003.69	22.13
4	3952.35	3847.45	3888.03	3895.94	52.90
5	3204.66	3028.16	2961.51	3064.78	125.64
6	2864.59	2846.15	2820.72	2843.82	22.03
7	3205.24	3136.03	3108.29	3149.85	49.93

Table2 The area measurements for large sizes (continued)

Pieces	Area (mm^2)				
	1	2	3	average	SD
8	4025.83	3956.88	4065.17	4015.96	54.82
9	2849.16	2808.03	2817.32	2824.84	21.57
10	2893.98	2802.09	2808.21	2834.76	51.38
11	2813.07	2822.17	2853.87	2829.70	21.42
12	2964.98	3116.67	3102.24	3061.30	83.72
13	2824.71	2809.27	2811.58	2815.19	8.33
14	3693.42	3953.53	3847.07	3831.34	130.77
15	2787.92	2857.14	2806.2	2817.09	35.87

3.2 Performance in object detection

The performance testing for the separation of flat dried banana sizes was conducted in three phases. In the initial phase, we focused exclusively on identifying small-sized flat dried bananas, totaling 50 specimens. Subsequently, in the second phase, our attention shifted toward identifying only large-sized flat dried bananas, also amounting to 50 specimens. In the final phase, our task was to detect both small and large-sized flat dried bananas simultaneously, totaling 50 specimens, with 25 from each size category. As demonstrated in Tables 3, 4, and 5, the results of our size-based separation tests across all three phases—small-sized only, large-sized only, and a mixed -size scenario—revealed an accuracy rate of 96.00%, 94.00%, and 94.00%, respectively. In the mixed-size scenario (small and large sizes), errors occurred due to misidentifying 2 large size and 1 small size. These errors from area calculations, which were caused by external light sources, image blurring, and noise from the conveyor belt's cleanliness. For the measured length, no error was observed. However, the position of the flat dried bananas being perpendicular to the motion path, as mentioned earlier, might be a potential cause. The discrepancies encountered during the separation process were primarily attributed to inaccuracies in calculating image areas, stemming from external light disturbances and the camera's shutter speed dynamics, both of which had noticeable impacts on image quality [20].

Table 3 **The accuracy percentage for small-sized flat dried bananas**

pieces	correct	incorrect	% accuracy
50	48	2	96.00

Table 4 **The accuracy percentage for large-sized flat dried bananas**

pieces	correct	incorrect	%error
50	47	3	94.00

Table 5 **The accuracy percentage for mixed small and large-sized flat dried bananas**

pieces	correct	incorrect	%error
50	47	3	94.00

4. Conclusion

A machine vision system is employed to categorize the sizes of flat dried bananas into two groups: large and small. This categorization is based on two key parameters, namely, the length and the surface area of the dried bananas. Through tests assessing its size-sorting capabilities, it has been demonstrated that the system can achieve an accuracy rate of over 90% in both large and small size categorization. This information indicates that the vision system can effectively substitute for human labor, as human workers may experience fatigue and make errors when working for extended periods. The inaccuracies in size sorting primarily arise from the computation of the banana's surface area, which is influenced by external lighting conditions and the camera's image quality. These two factors are the primary determinants impacting the precision of image-based detection.

Acknowledgements

The researchers would like to express our gratitude to the Department of Production Engineering Technology, Faculty of Industrial Technology at Pibulsongkram Rajabhat University, as well as the Department of Automated Manufacturing Engineering, Faculty of Industrial Technology at Rajabhat Rajanagarindra University, for their support in providing the necessary resources for this research. Additionally, thank you to the group of entrepreneurs involved in banana production in Phitsanulok province.

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The research interested in Machine Vision, Computer Vision, Automation.

Article History:

Received: February 2, 2024

Revised: June 30, 2024

Accepted: July 6, 2024