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Research article

Classifying scratches on chicken carcasses on processing line using two-dimensional image processing technique

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Abstract

Importance of the work: In Thailand, poultry processing has increased steadily. However, the selling price per carcass has dropped due to quality issues.
Objectives: To explore the possibility of detecting scratches on chicken skin during processing of carcasses.
Materials & Methods: A sample of 100 chickens was analyzed using photographs taken of each side for leg quarters with backbone on the midsagittal plane to categorize meat quality based on input from a specialist in chicken damage classification. An algorithm was developed to analyze each image based on sizing objects in pixels and the light intensity of extracted features.
Results: The first test resulted in an overall accuracy of detecting scratches of 68%. The main issue was that the program incorrectly identified shadows on the carcass as scratches. After adjustments to reduce errors from shadowing, the second test resulted in the algorithm correctly identifying 94% of the scratches. However, for certain samples, the algorithm was inconsistent with the quality level classification by the specialist because the specialist also considered the texture of the chicken skin during visual inspection.
Main finding: Using two identical cameras and light bulbs is recommended to capture better photographs and to enable more accurate in-depth analysis, supported by statistical data. The current results met the functionality requirements and should be developed further to assist automated quality inspection techniques in the future.

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Introduction

Chicken has become a main animal export product of Thailand, with both whole birds and cut pieces of chicken, whether fresh or cooked, experiencing a growing demand both locally and globally. For example, chickens were the first among livestock exports, making up 88.7% of the volume compared to other types of livestock and worth approximately 4,100 million USD in 2022, with most as processed chicken more than 72% of all chicken exports (Office of the Permanent Secretary Ministry of Commerce, 2022). According to studies in Thailand from 2018 to the present, very little chicken has been imported, while the quantity of exported chicken has increased every year (Preechajarn and Nicely, 2019; Prasertsri and Mullis, 2020). In 2021, chicken meat exports were expected to increase by 3–4% with a gradual recovery after the outbreak of the COVID-19 pandemic in 2020 (Prasertsri and Mullis, 2020). However, because of meat quality that is defective and rejected, the chicken selling price has decreased; if the products were of better quality, factories would buy chickens from farmers at a higher value, with processing benefits through lower production costs also, since the level of rejection would be reduced.

The chicken skin can be scratched or wounded, or both, during rearing, handling and transportation, as well as in the production process in the factory, with these marks decreasing the value of products and adding to the costs of slaughtering because inspection of poultry carcasses is required, to prevent problems of low-quality products being produced (Fletcher, 2002; Casey et al., 2011). Nowadays, human inspectors assist in detecting marks on the chicken skin. However, this step can delay the overall process and may result in discrepancies or a lack of trust by farmers regarding inconsistent scoring by individual inspectors. With the use of science and modern technology, a multi-spectral imaging system and image processing algorithms were developed to separate septicemic chickens from wholesome and inflammatory process chickens (Yang et al., 2005). A machine vision approach was used to segment the images of viscera of poultry carcasses. The image-processing-based visceral contour recognition method was applied for the extraction and detection of Three-Yellow Chicken and Cherry Valley Duck (Chen and Wang, 2018). When such research is tested on multiple species, it is important to develop a computer system that can recognize the images of certain species based on shape and texture (Pornpanomchai et al., 2013) or features, with the k-nearest neighbor algorithm a possible approach (Pornpanomchai et al., 2011). In another study, a line-scan machine vision system was used to separate healthy and diseased chickens at a dissection speed of 140 animals/min. The images were analyzed based on multispectral inspection of the 580 and 620 nm wavebands (Yang et al., 2010). Based on a machine vision approach, an automatic eviscerating robot system was developed for locating the chicken carcasses and the anal incision point (Chen et al., 2020). However, for digital image processing and neural network techniques to be more easily utilized, the digital images should be taken using an ordinary digital camera or a cell phone camera (Lurstwut and Pornpanomchai, 2017). The inspection system should focus on analyzing the colors and various flaws of the chicken meat before it is packaged and reaches the consumer (Barni et al., 1997).

Therefore, the main objective of the current study was to develop a technique for examining chicken carcass scratches using two-dimensional image processing techniques and to compare the results between an algorithm and a human inspector.

Materials and Methods

Data acquisition device and software

The device was installed on a production line at KVS Fresh Products Company Limited, a poultry slaughterhouse in Nakhon Sawan, Thailand (Fig. 1).

Fig. 1 Device setup in poultry slaughterhouse production line

An image acquisition unit was assembled in a manner that provided the best image resolution. Reducing photo noise can enhance perceived image quality. The device setup consisted of a Samsung Galaxy S7 smartphone, a phone tripod, a blue background cardboard sheet, a notebook computer and the LabVIEW software. The main camera on the smartphone used widespread 12 megapixel data capture with two photodiodes. A dual pixel sensor can focus quickly and accurately, with its bright F1.7 lens and large 1.4 µm pixel size performing well in low light conditions. The camera timer mode can take three pictures with a short delay between images to obtain a better image when the object is moving. The phone tripod stabilized the smartphone and reduced any blurring effect. In the slaughterhouse, a full-sized tripod (as tall as possible) was required because the chicken carcasses were hanging from a high rail. The camera was positioned at the same height as the chickens. The background piece of cardboard had dimensions of 60 cm × 60 cm and 3 mm thick. The original image in JPG format was transmitted via a wired universal service bus connection from the mobile phone to the computer. The notebook computer was powered by an Intel Core i7 processor, a dual storage system, an NVIDIA GeForce graphics card and 16.00 GB of random-access memory and used the Windows 10© operating system. The LabVIEW software is a system-design platform and development environment for a visual programming language from National Instruments that was built to improve engineering productivity and to help tackle engineering challenges.

Image processing to detect scratches

Data acquisition started from taking a photograph in the brightest place on the carcass production line to obtain an RGB color image that was easy to analyze. The image resolution was 4,032 × 3,024 pixels. Pre-processing was the first important step in image processing that commenced with converting the RGB color image to a grayscale. Then, LabVIEW created a control image using IMAQ Create to specify the image type (grayscale, RGB or HSL). The owning palette of IMAQ Create which is a part of NI Vision Development Module is "Image Management" palette that constituent in "Vision and Motion" functions. Grayscale images represent intensities of pixels ranging from least intense (black) to most intense (white). Pixel values usually range from 0 to 255. Grayscale U16 was the type used for this research, converting an image to standard monochrome and unsigned 16 bits per pixel.

Fig. 2 shows the threshold and the minimum-maximum pixels, which were tested and set as defaults in the LabVIEW program. Thresholding is the simplest method of image segmentation by splitting an image into smaller segment or pixels. These defaults provided the rules for detecting any object in the LabVIEW program within the focus of the study, in this case being a scratched area on a single chicken carcass. Additional tests with multiple images would be more accurate for object detection using computer vision based on Roboflow and TensorFlow for preliminary tests.

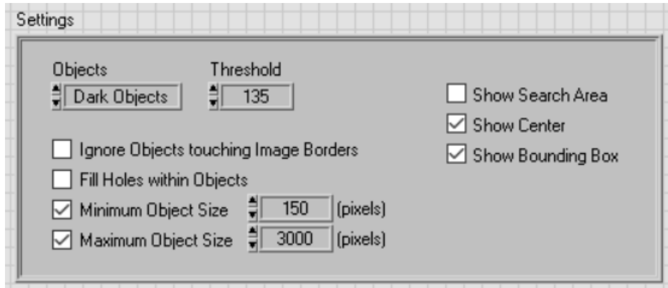

Fig. 2 Threshold and minimum-maximum pixel settings

The threshold value was previously set at a default of 128. According to several test parameters with different images, a replacement value of 135 (white) was defined for better data acquisition. The default values for the minimum and maximum object sizes were previously set between 3 and 100 pixels. However, these parameters were not compatible with an image resolution of 4,032 × 3,024 pixels. Consequently, a minimum object size of 150 pixels and a maximum object size of 3,000 pixels were set to filter out small details that were not scratches and not important in the analysis, while also avoiding errors such as counting the chicken frame as a scratch. Feature extraction effectively reduced the amount of data that must be processed to sort data into the different quality levels. The characterization effect was obtained from the total number of dark objects that reflected total scratches (Lee et al., 2013).

With the new set of parameters, the dark objects detected started to define a cluster on the image. The number of dark objects located in the search area based on input was the initial result in numerical format. This number was compared with poultry quality values defined upstream and then transformed into Boolean form to show the result as a green switch in each button for Level A, Level B and Level C. The algorithm that was used in this study created a decision tree model for classification of chicken quality. Criterion design for quality level sorting was derived with the assistance of a specialist who performed a visual inspection on the same set of 30 chicken images. The system tested five images of the left side of chicken carcasses at level A and recorded the number of programmable scratches. The same procedure was replicated for levels B and C. The system was then used to replicate the right side of the chicken. Based on these preliminary tests, a criterion range for each level in Table 1 was defined by the number of perceived scratches.

Table 1 Quality standard levels classified by number of scratches

Quality level	Number of scratches
A	0–19
B	20–29
C	More than 30

A dataset of 30 chicken images was inspected and sorted into a Boolean pattern which is a data type with two possible values, as displayed in the block diagram shown in Fig. 3. The program allocated +1 if true and +0 if false, according to the condition met for each quality level. The functional blocks used were "greater than or equal" and returned 1 or 0 as Boolean actions. Every chicken checked produces a value of 1 for a true result. Fig. 4 shows the program proceeding from entering data to grading chicken quality using the number of objects as a condition. The program also stores the total data analyzed.

Scratch detection and displaying result

Images were imported into the program National Instruments Vision Builder AI 2019 by extracting data from files in the work folder. Pre-processing started with converting an RGB color image to a grayscale image (U8) and (U16), as illustrated in Fig. 5. A border defined the object of interest. The scratch characterization calculation was determined from the number of objects of interest within the image (dark objects).

RGB and HSL images were not available for intensity image processing. Furthermore, grayscale images with different pixel values, such as 8 or 16 bits, did not produce differences for the objects of interest as a signed integer counted the dark object as an unsigned integer.

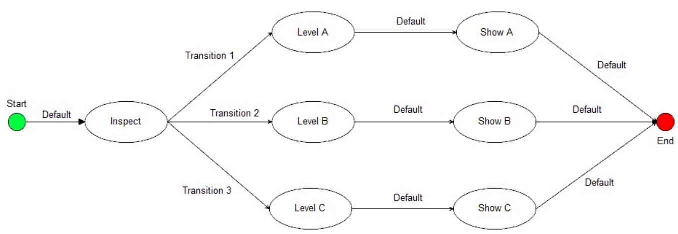

Fig. 3 Block diagram based on quality level analyzed from chicken image dataset

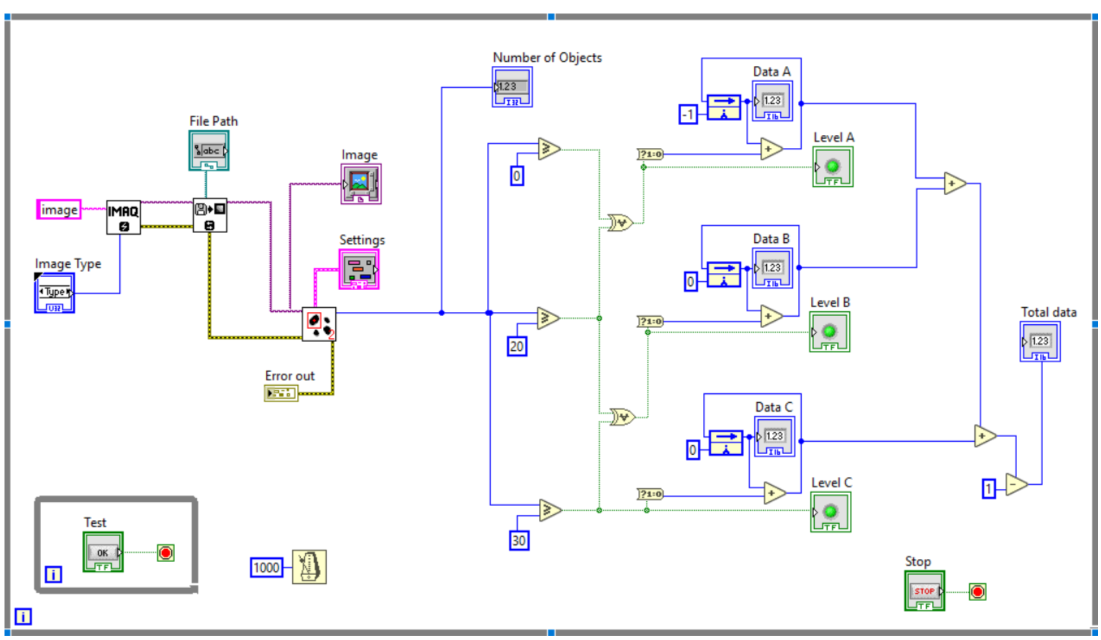

Fig. 4 Block diagram in Labview program

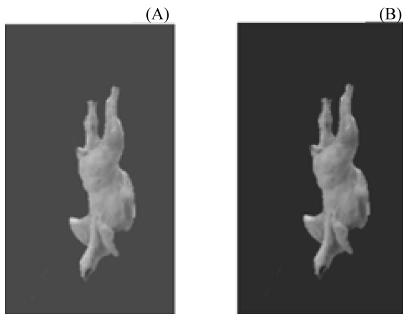

Fig. 5 Conversion of RGB color image to grayscale: (A) U8; (B) U16

However, converting to floating-point pixels caused an error in this image analysis. Consequently, the current analysis used a grayscale image type (U16) to analyze the image with 16 bits per pixel.

After new sets of parameters were used, the program issued a Graphical User Interface with details on three parts: input image, output image and the results values in numeric and alphanumeric format. Scratches, which were considered black objects in this image processing, were framed in red and counted for predefined quality level classification. Every piece of data collected during the image processing tests was presented as total data counted, for each quality level. An example on the front screen of the LabVIEW program is shown in Fig. 6, for an output image that was detected and based on 10 dark objects. These detected objects were classified at quality level A with a Boolean action that lights up at level A. The program detected 12 images that had been classified, with 7 images at chicken grade A and 5 at grade B. The testing process was carried out iteratively until achieving a final cumulative total data of 100. This approach was applied to the quantity of chickens categorized as either A or B quality.

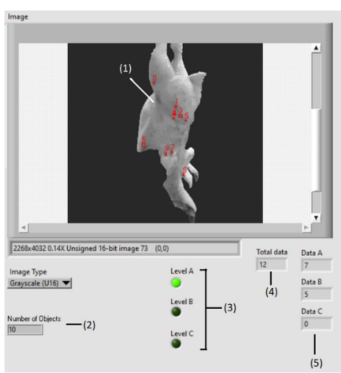

Fig. 6 Program results display: (1) output image for detecting dark objects; (2) total number of objects detected in the image; (3) perceived quality level; (4) cumulative number of verified chickens; (5) number of chickens allocated to each quality level

All data were acquired and analyzed by the specialist and the accuracy of the results are shown in the next part. First of all, the test was carried out with the background editing and removal of images.

Experimental procedure

The objective of this experiment was to test the performance of the developed algorithm and to develop a suitable technique to check the scratches on a chicken carcass on the slaughter line. First, the operator took a photograph of each chicken under lighting control for easy image processing. Then, the images were saved and stored in a work folder in the program National Instruments Vision Builder AI 2019. The image was loaded from the work folder to be processed and processing efficiency was compared between the software and human inspection. The human specialist set the standard in the evaluation; 100 chickens were divided into 50 samples for each side of the chicken and chicken quality was classified based on the size and shape of scratches or other wounding.

Test scores

In a company, working time can be an important indicator of the efficiency of the profession. In the current study, all work components during the detection process were timed, from taking the photograph to analysis on the computer. The working capacity of this research was the number of chickens per time spent (birds/minute). In addition, the scratch level detection accuracy was measured as a percentage, based on Equation 1:

$$\text{Detection accuracy} = \frac{\text{Accuracy count}}{\text{Number of chickens}} \times 100 \quad (1)$$

Finally, the scratch detection accuracy was compared between the developed algorithm and the regular method used by the human employees. The results were analyzed and presented in table form. The errors in each case were analyzed to determine the factors producing inaccuracies in the detection program.

Results and Discussion

Determination of parameters for data acquisition

The hanging chicken carcasses were photographed at a dissection speed of 120 animals/min, as defined by the factory. During the photographic process, the photographs were not very clear due to working at this speed. Furthermore, the positioning of the carcass had to be precise to obtain a photograph suitable for the identification of the carcass quality. Therefore, the camera's timer mode was used to attempt to take better pictures, by capturing three pictures after a delay.

The photographs were selected and divided into two groups, consisting of the left side and right sides of the chicken. Although taking the photograph from the front was easier than from the side and the frontal plane presents every chicken part, this did not provide suitable photographs for the studied image processing technique. Most scratches presented on the leg quarter with the backbone on the midsagittal plane. From the photograph of each chicken side, it was found that the amount and appearance of the scratches varied. Chickens were graded as 1–2 marks, 3–5 marks and more than 5 marks for levels A–C, respectively in reality. These levels equated to standard calibration with the number of objects using developed techniques in LabVIEW as 0–19 marks, 20–marks and more than 30 marks for levels A–C, respectively.

The photographs were taken on the production line, with more than one chicken being presented in some pictures, which present a challenge. The tests showed that the identification of the quality of the targeted chicken carcass was complicated without removing the non target chicken carcasses in the background. Therefore, before image analysis, the image should be edited to have only one chicken presented on the blue background, as shown in Fig. 7. Sometimes background images have been reported as a problem in detection (Jain and Chadokar, 2015). The Adobe Photoshop software can edit pictures and remove the background. In the current study, non target details were deleted and filled with blue color.

Results of analysis and comparison

The performance of the developed technique was analyzed by comparing its classify ability with the results of the specialist, based on the specialist setting the standard in the evaluation. The sample of 100 chickens was divided into 50 samples for each side. For the first test, the overall accuracy of detecting scratches was 68%. All errors were studied and differentiated, as shown in Fig. 8. There were more errors on the left side than on the right side due to the problem incorrectly grading shadows on the chicken carcass as scratches. The shooting position for each side did not have a controllable light source to illuminate the target subject directly. Thus, the number of shadows on each side of the chicken depended on the lighting location in the slaughterhouse. Shadow has been reported as one of the problems in detecting a particular object from a series of other objects (Jain and Chadokar, 2015). Additionally, sometimes the program identified some parts of the chicken as a bright object. In such cases, the program was unable detect tear marks on the chicken skin. Other errors were attributed to an unspecified program error.

The analysis indicated that several photographs of the chicken carcasses were not valid for image processing. However, they helped to identify actual work-related problems and to deal with these problems to improve the conditions for the next test. Shadows were the factor that was the most serious problem. Further study was carried out to determine whether the algorithm could improve on the overall scratch detection accuracy or 68% if there were no shadows.

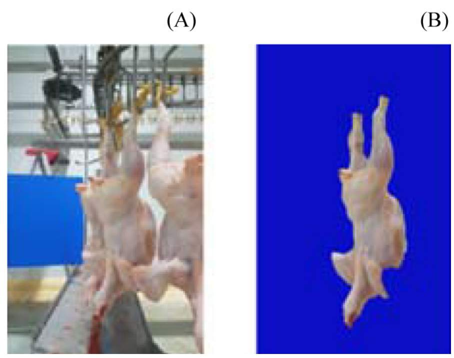

Fig. 7 (A) original picture taken on production line; (B) edited target carcass with background replaced with blue background

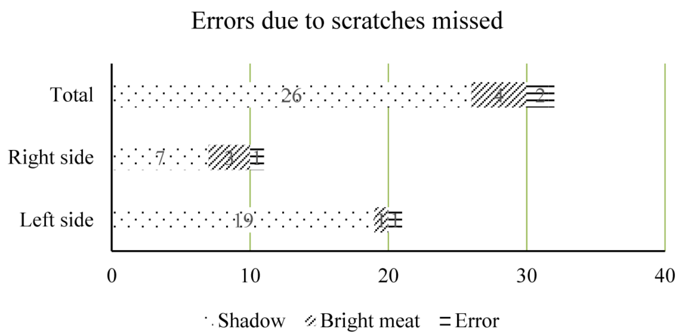

Fig. 8 Errors in image processing algorithm results for detecting scratches

For the second test, the lighting was adjusted to reduce incident shadowing. Then, the samples were classified for quality level based on the specialists' judgment and compared to the developed technique, as shown in Table 2. Removing the shadowing effect resulted in the algorithm classifying the quality levels of the chicken carcasses to an accuracy of 94%. For some samples, the quality level classification based on the algorithm was inconsistent with the specialist's judgment, with five birds classified as level A by the algorithm that were classified as level B by the specialist due to the fact that the texture of the chicken skin was also considered in the visual inspection. However, the developed technique in this research recognized only scratches or defects on the chicken skin as a condition for classification; since other quality characteristics (such as skin texture) were not included, some classification errors resulted. In addition, one chicken classified by the specialist as level B was incorrectly classified as level C by the algorithm due to missing information for level C during data acquisition (on the day of data collection, level C quality chickens were not presented).

Table 2 Results of analysis and comparison of quality classification methods between operator and developed techniques

Side	Level	Number of chickens (carcasses)		Annotation
		Operator	Developed technique	
Left	A	44	45	1 must be level B
	B	6	4	
	C	0	1	1 must be level B
	Total	50	50	
Right	A	42	46	4 must be level B
	B	8	4	
	C	0	0	
	Total	50	50	

Conclusion

An image processing technique was successfully developed for examining the scratches on the skin of a chicken carcass distinctive features based on the light intensity and the area calculated. The algorithm was able to correctly identify 94% of scratches on chicken carcasses by detecting dark objects that satisfied the feature conditions. Chickens with more than 30 scratches must be tested to obtain calibration data for the C data because the current study could not appraise any Level C carcasses on the day of data acquisition. A new range of classification levels might result from the inclusion of the additional calibration sample. Two identical cameras and light bulbs are recommended to take better photographs and to facilitate more accurate in-depth statistical analysis. Open-source software, such as Roboflow and TensorFlow, are recommended for machine learning to expedite labeling, with particular focus on the formation and inference of deep neural networks. These could be used to adapt the current algorithm for automatic testing without the need to manually change or remove the background in carcass images. Integration of the controlled factors (the configuration of the camera and program, and other relevant quality characteristics) should allow for more accurate classification. Consequently, better quality inspection techniques could be developed from this study to progress automated inspection systems and machine vision applications.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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