Development of Citrus Grading System Using Image Processing

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Abstract

Citrus is one of important fruits in Indonesia and its production increasing from 449.5 thousand tons in 1999 to 2.5 million tons in 2006, although slightly decreasing to 2.2 million tons in 2009. So far, citrus has been graded manually by the traders and processors into 5 classifications A, B, C, D, and E not conformed to SNI (Indonesian National Standard) 01-3165-1992 which has established four grades for citrus ranges from A to D. The objectives of this study were to develop software using image processing to evaluate and grade citrus based on their weight and color, and to develop a real-time grading machine prototype for citrus classification using the software.

Citrus was evaluated for its size by image processing analysis. Data of the area of each citrus in image captured using a CCD camera attached to a grading machine prototype was transformed to the weight of citrus and used for classifying the citrus conformed to SNI grades. The results was then compared to the ones from manually grading. The prototype consist of a rotating fruit feeder with two pneumatic solenoids that open and close one after another to release one fruit at a time, a belt conveyor to convey the fruit, a color CCD camera located in an image acquisition chamber with lighting system for image capturing, four openings that open and close each accordingly to a different fruit grade of citrus, four collecting boxes for graded citrus, a logic control panel for computer interfacing, and a computer with an image frame grabber to process the captured image.

The results of experiment using the prototype of grading machine indicated that citrus graded by image processing conformed to SNI at a degree of 96% compared to 41% performed by manual grading. The capacity of the grading machine prototype was 700 fruits/hr.

Key words : citrus, grading system, image processing, real-time grading machine prototype

Introduction

Citrus production in Indonesia has been increasing to a yield of 17-25 tons/ha. However, the quality is still a serious problem. Most of the citrus produced from the production centers such as Pontianak (West Kalimantan) and Medan (North Sumatra) enter domestic market with unattractive appearance with big varieties in size, color, and taste. For that reason, the quality improvement of citrus through the development of quality assurance system using new technologies is necessary. Many postharvest handling technologies such as waxing and modified atmosphere packaging can be applied, but uniformity in size, color, and taste is very important in marketing the products. Size and color are the two essential parameters for the citrus fruit quality often used by the consumers in justifying their purchase.

Automation in agricultural engineering might be employed based on consideration as follows [1] : 1) there are many laborious and monotonous tasks that are not suited for human, but require certain humanlike intelligent to perform, 2) the availability of farming labors is decreasing in some places, 3) the labor shortage problem results in high labor cost, and 4) demand for better quality products has been more and more important issues. For Indonesia, cases 1, 2, and 3 are not greatly relevant, but case 4 is a priority in making the local products more competitive in value and price compared to the imported products. That is why the usage of advanced technology is necessary to produce a good quality fruits, especially in sorting and grading method.

One of the advanced technologies that can be used for sorting and grading fruits is an automatic grading system with image processing for quality measurement. Image processing technology is a technology developed to obtain information from image by modifying the image into a desired and more informative one and analyzing it. Whenever image processing is integrated with a unit where the obtained information is used to drive a part of the unit system to do specific task, it is called machine vision [2]. Image processing technology has been applied to detect cherry tomato in a bunch of cherry tomato plants by recognizing object with different color. The method was integrated in the harvesting robot for cherry tomato cultivated in a greenhouse [3]. Another example of image processing application is in mushroom harvesting robot, to detect the mature mushroom to harvest [4] and in watermelon harvester to do the same task [5].

The objectives of this study were to develop software using image processing to evaluate and grade citrus based on their weight and color, and to develop a real-time grading machine prototype for citrus classification using the software.

Materials and Methods

Citrus samples were collected from Pontianak, West Kalimantan, the largest production area in Indonesia, and evaluated for its area by image processing analysis using a developed still image processing software. Data of the area of each citrus in image obtained from a CCD camera attached to a grading machine prototype was transformed to the weight of citrus, and was used for classifying the citrus conformed to SNI grades, after the threshold levels for each grade were calculated and inserted in the real-time image processing program developed after still images analysis.

The machine prototype was designed and constructed from the following components a rotating fruit feeder with two pneumatic solenoids that open and close one after another to release one fruit at a time, a belt conveyor to convey the fruit, a color CCD camera located in an image acquisition chamber with lighting system for image capturing, four openings with three pneumatic solenoids that open and close each accordingly to a different fruit grade of citrus, four collecting boxes for graded citrus, a logic control panel for computer interfacing, and a computer with an image frame grabber to process the captured image. The real-time image processing computer program was developed to run and control the machine during the experiment.

Eight hundred and fifty of Pontianak citrus, composed of 125 grade A fruits, 125 grade B fruits, and 200 fruits each for grades C, D, E respectively, were used as samples. These samples were from Pontianak (West Kalimantan), but graded manually based on size by a big trader in Jakarta. These samples were used in the experiment to observe performance of developed real-time image processing program that implemented in the prototype of grading machine, as well as to assess the performance of the machine in grading the citrus automatically. The results of image processing classification was then compared to the ones from manually grading, while the performance of the machine was observed for its capacity. In comparing the results of classification between that resulted from the developed real-time image processing program and that resulted from the manual method, a recent national classification standard based on SNI 01-3165-1992 was used as a reference.

Results and Discussion

Re-grading of 850 citrus samples collected from West Kalimantan based on their weight using a digital balance and the SNI criteria resulted in 91 fruits grade A, 269 fruits grade B, 467 fruits grade C, and 23 fruits as grade D. The variance to manual grading applied in the current practices in the supply chain of citrus was listed in Table 1.

Data from Table 1, indicated that there were 323 fruits (38%) which were different from SNI grades. The differences fell heavily in grade B (54 %) and C (81 %). Most of the fruits were

Table 1. Variance of manual grading to SNI 01-3165-1992 citrus grade

SNI Citrus Grade	Manual Grading					Amount
	A	B	C	D	E	
A	91 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	91
B	34 (13%)	124 (46%)	111 (41%)	0 (0%)	0 (0%)	269
C	0 (0%)	1 (0%)	89 (19%)	200 (43%)	177 (38%)	467
D	0 (0%)	0 (0%)	0 (0%)	0 (0%)	23 (100%)	23
Total fruit	125	125	200	200	200	850

classified into lower grades such as 41 % grade B was considered into grade C, and 81 % grade C into grade D or grade E. This caused heavy losses for the growers.

Fig. 1 illustrated the sorting and grading machine prototype. Even though the real-time image processing program was able to utilize two visual parameters for citrus classification, size and color, this experiment only used size as the grading parameter. The prototype had four outlets, referring to four grades declared in SNI used as a reference. The color would be accommodated for future development to obtain a more uniformity visual appearance for each grade, when the combination of size and color for the citrus grading provided a sufficient incentive for the growers.

Figure 1. Automatic sorting and grading machine prototype for citrus

The rotating fruit feeder and the belt conveyor were actuated by two different electrical motors, which were controlled by the developed computer program. Two pneumatic solenoids were used for the feeder that open and close one after another to release one fruit at a time, and three pneumatic solenoids were used to open and close the three openings for A, B, and C grades, which were also controlled by the same developed computer program. The fourth opening for D grade was left to be open. A photo sensor was placed in the image acquisition chamber to detect the passing fruit.

Furthermore, the same samples were graded based on size of fruit, or area projection of the fruit in image processing using the developed computer program. The relationship of the weight of citrus fruits with their projection area could be expressed by the following equation $y=205x+7018$ with y as the projection area (pixel) and x as the citrus weight (g). Based on the equation, the classification borders used in the computer program was described in Table 2.

Table 2. Determination of threshold values according to the SNI classification based on the citrus weight

SNI Citrus Grade	Weight (g)	Threshold Values (pixel)	
		Lower	Upper
A	> 151	37919	-
B	101 – 150	27687	37918
C	51 – 100	17456	27686
D	≤ 50	-	17455

By inserting these threshold values into the developed real-time image processing program, which also had the ability to control the CCD camera, two electrical motor and three openings, the grading machine can run and classified the citrus into A, B, C, or D grades automatically. The results of grading using the machine and their variance to SNI was listed in Table 3.

Table 3. Variance of grading by image processing to SNI 01-3165-1992 citrus grade

SNI Citrus Grade	Grading by Image Processing				Amount
	A	B	C	D	
A	84 (92%)	7 (8%)	0 (0%)	0 (0%)	91
B	2 (1%)	263 (98%)	4 (1%)	0 (0%)	269
C	0 (0%)	17 (4%)	436 (93%)	14 (3%)	467
D	0 (0%)	0 (0%)	0 (0%)	23 (100%)	23
Total fruit	86	287	440	37	850

In average, grading by image processing agreed with SNI at the level of 96% for the overall grades, which was reasonable. In other words, grading by image processing produced uniform citrus in size for each grade, and grading was done accordingly to Indonesian standard for citrus. Citrus fruits classified into lower grades were 8 % from grade A into B, 1 % from grade B into C, and 3 % from grade C into D. However, there were also some fruits upgraded to a higher class : 1 % from grade B into A, and 4 % from grade C into B. From the experiment, it was known that the capacity of the grading machine was 700 fruits/hr. To scale up the prototype to a commercial use in the field, further improvements should be done.

Conclusion

The developed prototype for automatic grading machine with image processing as quality evaluation method had been performed successfully to the designed function. The results indicated that citrus graded by image processing conformed to SNI at a degree of 96% compared to 41% performed by manual grading. However, the capacity of the grading machine was 700 fruits/hr, thus it needed further improvements, especially in speed, before the implementation in the field.

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