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DEVELOPMENT AND TESTING OF AUTOMATIC GRADING MACHINE FOR CITRUS

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ABSTRACT

Citrus is an important fruits in Indonesia and its production increases from year to year because citrus is one of the fruits supported by national fruits development program. However, postharvest equipment for citrus is very limited, leading to low postharvest technology utilization. The objective of this research was to develop and test a real-time grading machine for citrus using an image sensor and processing unit for quality evaluation of the acquired image of the citrus being evaluated. The grading machine consists of a rotating fruit feeder, a belt conveyor, a color CCD camera placed in an image acquisition chamber, four channels to pass four different grades of citrus, four collecting boxes for graded citrus, a logic control panel, a computer with an image frame grabber, and a software to run all the installed hardware. The rotating fruits feeder and the conveyor are actuated by two different electrical motors. The constructed machine then was tested to observe if all the hardware worked well, and the result of citrus classification were also observed visually to determine the performance of the machine. The result of testing showed that the machine could work properly as it was design, and the classification of citrus could be done based on the size as current manual work, or even based on the size and color of skin as an improvement. However, the speed of the machine is still very low and some problem with the feeder is still happening, especially when citrus variation in size was big.

***Keywords**: citrus, image processing, grading machine*

BACKGROUND

Citrus is an important fruits in Indonesia and its production increases from year to year because citrus is one of the fruits supported by national fruits development program. The government of Indonesia, through the ministry of agriculture, has a program to increase local citrus production and consumption to replace import citrus, and later on to export high quality citrus to other countries. The production increases from year to year since 1999 and in 2006 the volume of production was about five times of that in 1999. The increase of citrus production in Indonesia both due to extensification and intensification programs. The extensification program increases the harvest area of 25,210 hectars in 1999 to 67,152 hectars in 2006, while the intensification program was able to increase tonage production per hectar of citrus from 17.83 ton/ha in 1999 to 36.93 ton/ha in 2006. As a result, total production of citrus in Indonesia has increased from 449,531 tons in 1999 to 2,479,852 in 2006. The complete data was shown in Table 1.

Table 1. Increase of citrus production in Indonesia during the year of 1999 - 2006 (Ministry of Agriculture, 2008)

Year	Criteria		
	Harvest area (ha)	**Production (ton)**	**Productivity (ton/ha)**
1999	25,210	449,531	17.83
2000	37,120	644,052	17.35
2001	35,367	691,433	19.55
2002	47,824	968,132	20.24
2003	69,139	1,529,824	22.13
2004	66,071	1,994,760	30.19
2005	62,578	2,150,219	34.36
2006	67,152	2,479,852	36.93

While the production of citrus is increasing due to government program, some problems in postharvest technology remain exist. The main problem found for citrus in Indonesia is low quality product due to poor postharvest technology. Most of the citrus arrives in the market with mix quality and visually not attractive for buyers. The citrus available in Jakarta from production center like Pontianak in West Kalimantan, enter the market in different size, color that are not uniform, and dirty because of dust sticks on the skin during the growing period in the field. Increasing in quantity but not in quality causes some other problems such as oversupply since the captive market is the same, and this problem will cause decreasing in price that will cause another serious problem in the farmer's side. Furthermore, low quality citrus will not suitable for export to othe countries, even will not be able to replace import citrus, and this means the national program is not successful.

To increase the quality of local citrus in general, quality assurance system for citrus is necessary to develop, through these actions.

1. Government policy to support citrus program
2. Adequate infrastructure and facility
3. Information system
4. Supporting institutions and management, both in farmer level to increase the production, and in higher level to facilitate marketing
5. Appropriate technology for the farmer, both preharvest and postharvest technology
6. High capacity human resource

In the free trade in the near future, high quality product is a must to compete with the same product from other countries, even to sell the product in the local market.

Moreover, to export the citrus to other countries, quality standard is determined by importing countries, which might be higher than the standard applied for local market. Many countries apply new standard with Good Agricultural Practices (GAP) application in different names such as Malaysian Field Accreditation Scheme in Malaysia, Australia with Fresh Care regulation, New Zaeland with Approved Supplier Program regulation, England with Assured Produce Scheme regulation, and European Union with EUREP GAP. These regualtions are mostly applied in the production field, in the on-farm activities.

For the off-farm activities where the postharvest technolgy is needed, process automation is very important to maintain quality of the product. Automation in agricultural activities is considered necessary based on the following reasons; 1) although many agricultural operations have been mechanized, many taks are still laborious and monotonous which are not suitable for human, but require certain intelligence to perform, 2) the availability of farming workforce is decreasing at an alarming rate in many countries, 3) the problem of labor shortage frequently result in rising in labor cost, and 4) the market demand for product quality has becaome an important factor in bioproduction (Kondo and Ting, 1998).

In the case of Indonesia, the first, second, and third reasons might not apply, but the fourth one is very relevan in the free trade era, especially for export market. Therefore, the use of high technology in postharvest handling of fruits for export is necessary to consider, planned, and developed from the beginning of fuits development program in Indonesia.

Many researcher has tried to use high technology for agricultural products quality evaluation. Near infrared (NIR) technology can be used to predict sucrose content and malic acid in the fruit flesh so NIR can be used to measure non-destructively as an opposite of destructive analysis such as HPLC method to measure important content of fruit flesh. The research reports show that NIR technology has been used to measure sucrose content without cutting off the fruit such as in tomato (Suparlan and Itoh, 2001), in peach (Kawano et al., 1992), and in apple (Murakami et al.,1994). In the developed countries, this technology has been applied in sorting and grading machine and other types of quality control machines for agricultural products including fruits. In Indonesia, this kind of technology is very expensive to be used in agricultural products due to the price of the prodcuts that relatively low. However, if the price of the products increases by shifting from local market to export market, the price of high technology might no longer expensive.

Another technology that can be applied in automatic sorting and grading machine is image processing. Image processing is one of many technologies developed to obtain important information from an object through its image that captured by any capturing device including normal camera. the important information of an object can be obtain through its image is done by modifying the image or convert the image into another more informatif image (Jain et al., 1995). A simple example for image convertion is converting color image into binary image, so that object inside the image can be separated from its background and analysis of the object can be conducted easily. If image processing technology is combined with a specific machine where the result of image analysis is used to take action by the machine, the system is called machine vision (Jain et al., 1995). In simple words, it can be said that the output of image processing is another image, while the output of machine vision can be an action, or other representation of the result. This technology is becoming cheaper and cheaper because rapid development in hardware for computer and other electronic parts including CCD camera. Moreover, integration of CCD camera and the computer is becoming easier by using many interface connection such universal serial bus and firewire which are commercially available, so that computer does not need an image frame grabber.

The use of image processing technology in automatic grading machine is expected to increase accuracy of fruit sorting and grading based on size and color of skin. Fruit condition can be approached from object size to represent fruit size, and the ripeness of the fruit can be represented by skin color, if there is correlation between the two. Another advantage is image processing can be used also to detect defect such as dried latex in mango, that might be exist on the fruit and downgrades the quality. Image processing technology has been tried to detect and locate cherry tomato among the leaves in cherry tomato plants by selecting suitable color signals, and the result of detection was used to drive cherry tomato harvesting robot (Kondo et al., 1996). Another example of image processing application is mushroom harvesting robot, which utilized image proceesing to detect and locate mushroom that ready to harvest (Reed et al., 1995), and watermelon harvesting robot, which also used image processing to do the same thing (Tokuda et al., 1995).

The objective of this research was to develop and test a real-time grading machine for citrus using a CCD camera as an image sensor and image processing unit for quality evaluation from the acquired image of the citrus being evaluated.

METHODOLOGY

Some important parameters of visual quality from different quality of citrus were studied by analyzing them using the developed image processing computer program. Formerly, five groups of different quality of Pontianak citrus (A, B, C, D, and E classes), obtained from a big trader in wholesale market in Kramatjati, Jakarta were used for samples. The images of the citrus were captured and then the captured images were analyzed using image processing computer program. The results of image processing were analyzed to determine whether there were parameters that correlates with size or weight of the citrus, sweetness, and firmness, to be used for quality evaluation. Visual parameters that figures the real quality of citrus will be selected to be used for quality parameters to develop a real-time quality evaluation system for citrus as first step in developing grading machine.

As the computer program to perform real-time quality evaluation of the citrus by analyzing its image was ready, the hardware needed for the system to run was designed and constructed, as the second step in developing grading machine. The hardware consists 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 placed in an image acquisition chamber with lighting system for image capturing, four channels with three pneumatic solenoids that open and close according to the fruit grade to pass four different grades 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.

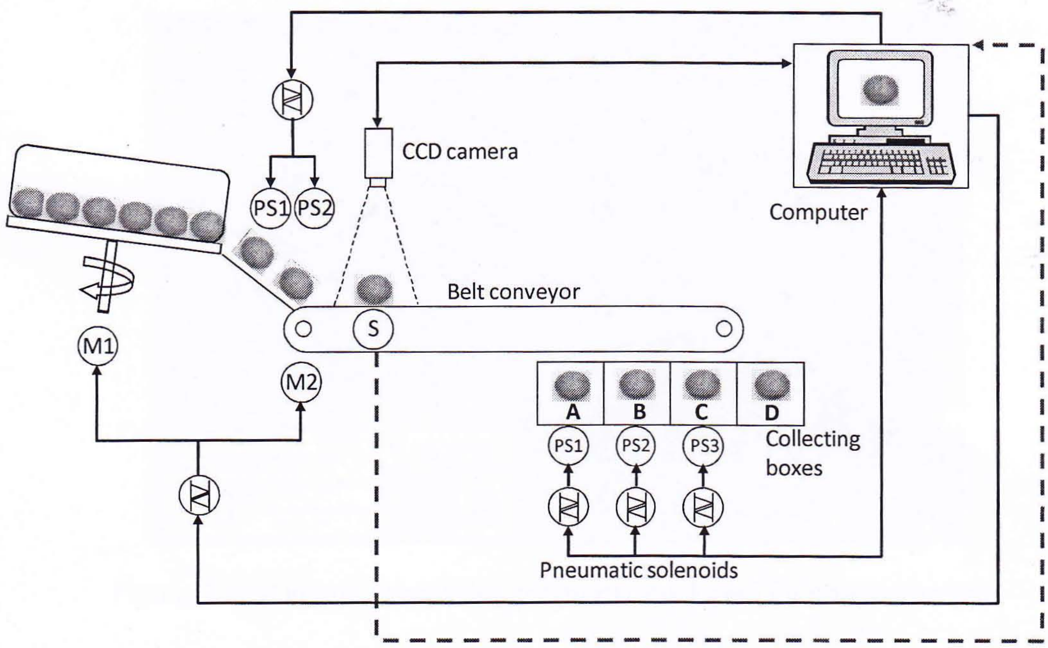


Figure 1. Schematic diagram of the automatic grading machine

All the installed hardware components communicates each other managed by a single computer program, which was also performing image processing for quality evaluation. Since the program for image processing was also controlled the hardware, the result of image processing was able to be used as information needed for quality judgement. The result of classification would be applied to separate the citrus according to its grade when they were transport through the belt conveyor, by opening one of the three channels according to the quality of citrus being moved to one of the collecting boxes, A, B, or C class. For D class, all the three channels will stay close and the citrus will enter the fourth channel that always open, as default condition. Schematic diagram of the automatic grading machine was shown in Fig. 1.

Finally, the automatic grading machine was tested to observe if all the hardware work well, and the result of citrus classification were also observed visually to determine the performance of the machine.

RESULTS AND DISCUSSION

In the first step, a still image processing program was developed and used to analyze all the sample images (Fig. 2). Every image was captured in 400 by 300 pixels resolution, and then was analyzed for the size of citrus represented by area of object in image, also sweetness and ripeness represented by skin color in RGB color model. The results of image analysis then were compared to the results of direct measurement, by weighing for the size or weight of the citrus, by portable Brix meter for sweetness, and by rheometer for firmness.

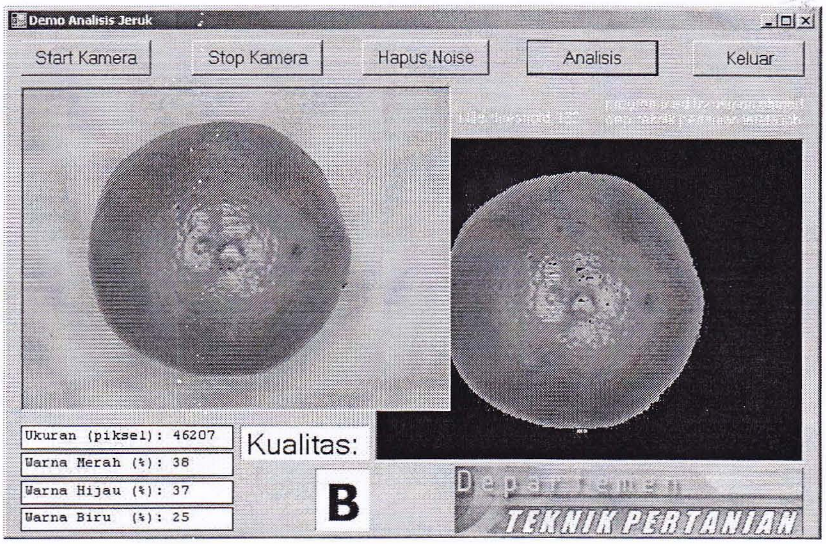


Figure 2. Still image processing program developed for image analysis

Among the area of the object to represent citrus size, and the skin color to represent the sweetness and ripeness of the citrus, only area that correlates with the size or weight of the citrus, as shown in Fig. 3. After that, area of the object was used to classify the fruits based on the size, using equation y = 205 x + 7018, where y is area (pixel) and x is weight (gram). Classification rules referred to Indonesia Standard for citrus (SNI 01-3165-1992) as shown in Table 1. The rules of classification then were insert to the real-time image processing program.

The skin color has no relationship with sweetness and ripeness. However, the skin color can be used to separate the citrus with different color that can be combined with the size. So, by applying area of the object

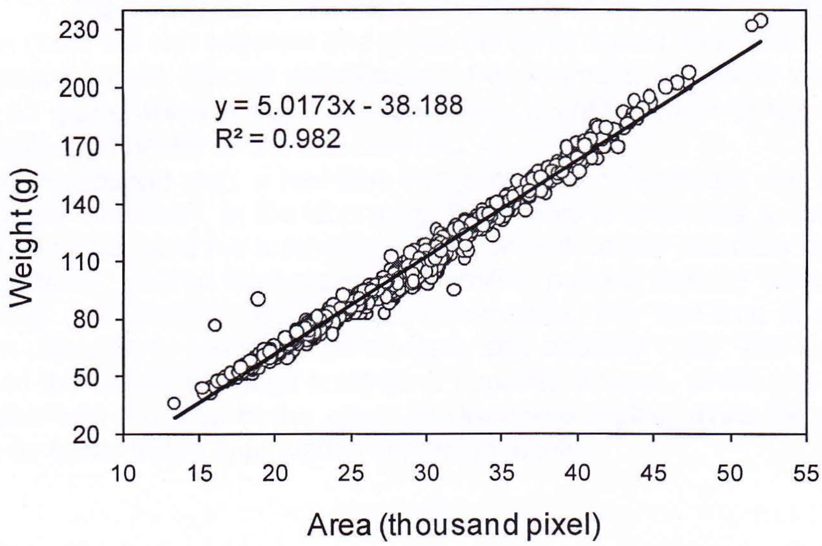
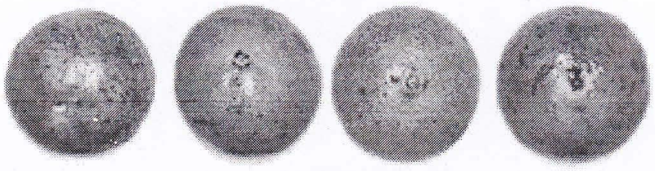


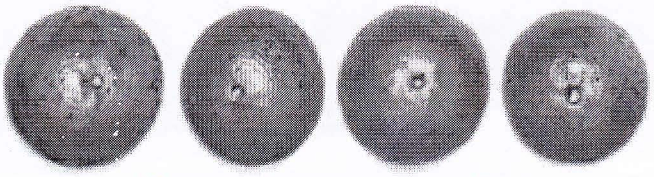
Fig. 3. Relationship between weight of the citrus with area of object

Tabel 1. Weight based classification criteria for citrus converted to pixel for area of the object in image

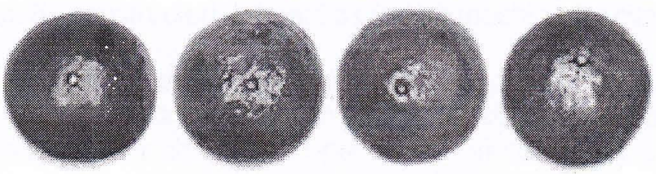
Class	Weight (gram/pc)	Area of object (pixel)
A	≥ 151	≥ 37919
B	101 – 150	27687 – 37715
C	51 – 100	17455 – 27483
D	≤ 50	≤ 17251



A1 grade: big and yellow



A2 grade: big and green-yellow



A3 grade: big and green

Fig. 4. Skin color can separate one into three different grades

and skin color, we can separate and grade the citrus based on the size and skin color, if necessary, to get diferent classification. For example, A1 grade which is big and yellow, A2 grade which is big and green-yellow, A3 grade which is big and green, and so on, instead of based on the size only (Fig. 4).

In the second step, a real-time image processing software was developed and tested in the laboratory. In the laboratory, the motors to rotate the feeder and to move the belt conveyor, and the solenoids to open and close the channels were substituted with light bulbs, so that the hardware controlling process can be demonstrated while the sorting and grading machine was constructed. The real-time image processing program utilized only two visual parameters, size and skin color. The size was chosen based on the results of image analysis of captured images, which was found to have correlation with the size of the citrus as discussed earlier, while the skin color was chosen for better visual appearance of grading result.

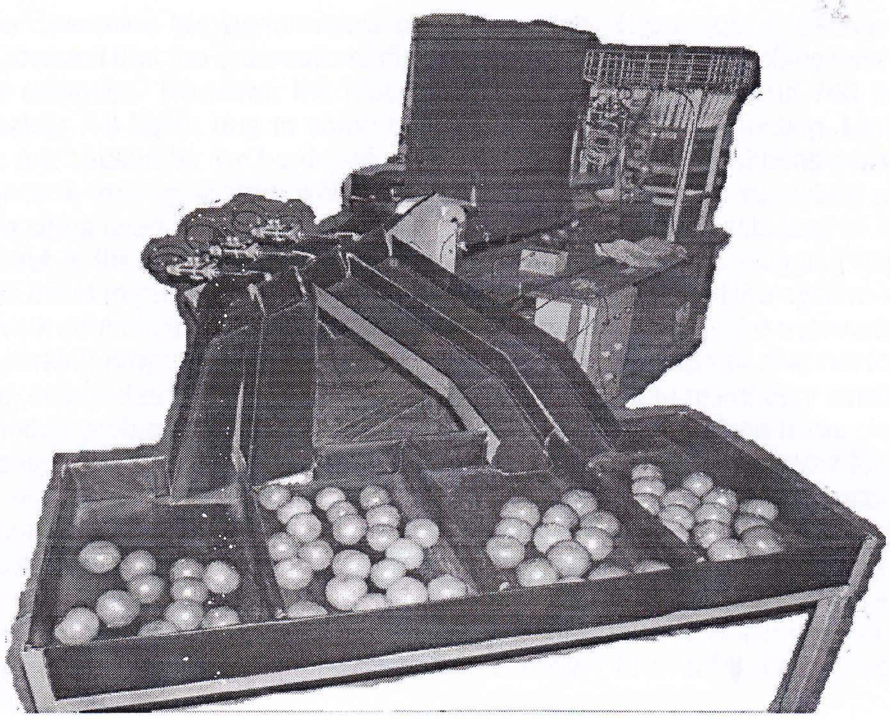


Fig. 5. Constructed automatic grading machine for citrus

The grading machine consists of a rotating fruit feeder with a channel, a belt conveyor, a color CCD camera placed in an image acquisition chamber, four collecting boxes for graded citrus, four channels to pass four different grades of citrus, a logic control panel, a computer with an image frame grabber, and a developed software to run all the installed hardware (Fig. 5). The rotating fruits feeder and the belt conveyor are actuated by two different electrical motors. Two pneumtic solenoids that open and close one after another to release one fruit at a time, and three pneumatic solenoids are used to open and close the three channels for A, B, and C grades, while the fourth channel for D grade is always open. A photo sensor was placed in the image acquisition chamber to detect the passing fruit. If there is a fruit, the photo sensor will send a signal to the system and the system will stop the electrical motor to halt the conveyor, and the CCD camera will capture and analyze the image of the fruit. The real-time image processing software then was sincronized to run all the hardware attached to the control system in the sorting and grading machine. For the testing, where the two parameters, size and skin color were used in classification, while the initial output grades were only four (A, B, C, and D), the output grades were changed into A1 (big and yellow), A2 (big and green), B1 (small and yellow), and B2 (small and green). This new classification was used for testing purpose only. In the future, if skin color is considered important for classification, more than four output grades are needed and the modification will not change the machanism of the system drastically.

After combining the developed hardware components and the real-time image processing program, the machine was tested to observe if all the hardware components worked well, and the result of citrus classification were also observed visually to determine the performance of the machine. The result of testing with the machine showed that the automatic sorting and grading machine for citrus was working as it was designed. However, the machine run very slow, only about 700 fruit/hr or approximately 7-8 kg/hr, due to some problems found during the testing. Most of the problems are caused by the hardware performance, one of the problems caused slow performance is feeding system which was not always successful, especially when the size of the citrus used as samples varied in big range. Two small fruits tend to leave the feeder outlet at the same time and caused a clogging. When the clogging happened, the feeder failed to put one citrus at a time on a belt conveyor and the system stopped. Manual work could help to overcome this problem, but that means the automatic feeder was not working properly as it is expected. More accurate design of channel for feeder is needed, or pre-classification of the citrus might be needed to reject very small citrus.

Another problem that caused slow performance of the machine is the movement of belt conveyor that was also too slow. Speeding up the electrical motor for the belt conveyor was possible to do to eliminate this problem, but the fruit tends to slip and the fruit position on the belt conveyor when it entered the image acquisition chamber was not in the center of frame anymore for camera to capture. Beside, fruit slip on the belt conveyor caused distance between two fruits was not uniform and sometimes two fruits were entered the image acquisition chamber at the same time which caused another problem in image processing. More rough belt conveyor to avoid the slip is needed to overcome this problem.

CONCLUSIONS

From this research, two important information has been obtained and can be cocluded as follows:

1. Image processing can be used to classify citrus into several quality classes based on the area of object to represent fruit size according the quality standard issued by the government. Skin color can also be used as additional parameter to get more uniform color after classification.
2. The designed and constructed automatic grading machine with image processing as quality evaluation method has been tested and worked as it was designed. However, the capacity is still very small and still need many improvements before putting it into practice.

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