Design to prediction tools for banana maturity based on image processing

Sandra, I Y Prayogi, R Damayanti and G Djoyowasito

Department Agricultural Engineering, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia

E-mail: sandra.msutan@ub.ac.id

Abstract. Image processing is a method to process image become information consisted of phisycal condition of product. Image processing applications in agriculture are currently developing very rapidly, especially for the prediction of fruit quality and maturity. The purpose of this study is to design a tool to predict the maturity of bananas. The type of banana used in this study is barlin banana (Musa paradisiaca. L) with maturity levels 1, 3, 5 and 7. While the image processing characteristics use data R, G and B which are captured by the TCS3200 sensor. From a number of experiments, a distinguishing factor is obtained for the RGB value for each level of maturity, maturity 1 with the value of G> B; maturity 3 with Value R> G, Value (R-G) <9 and G Value ≥ 142; maturity 5 with a value of R> G, a value of 9 ≤ (R-G) and a value of G ≥ 142; maturity 7 with a value of R> G and a value of 142 ≥ G. The results of the prediction of the banana maturity using this tool for maturity 1 accuracy prediction 100%, maturity 3 accuracy predictions 80%, maturity 5n accuracy prediction 100% and maturity 7 accuracy predictions 60%.

1. Introduction

In Indonesia, the marketing of bananas is still fairly low because it does not have an export market for bananas that accommodate farmer production [1]. Whereas, local bananas are only marketed domestically, especially barlin or diamond bananas (Musa paradisiaca L.). This is due to the demand of consumers who want the condition of bananas with clean and without defects of skin quality. Post-harvest handling is very important to maintain the quality of agricultural products.

One of the post-harvest handleings that need to be considered is the level of aging and age prediction of storing bananas for marketing purposes. Therefore, a tool to help banana farmers predicting the maturity level of bananas is needed. Thus, farmers can determine the marketing objectives that are appropriate to the maturity of the banana. The maturity of bananas is marked by the color changes of bananas, from green to yellow [2]. The color changes can be seen visually or they can be seen from their appearance. These color changes can be used in image processing technology to predict the level of aging in bananas so that it will be known for subsequent post-harvest handling. Sorting and grading using colors has been done by previous researchers, for tomatoes [3], physical-chemical characteristics at various maturity [4].

One sensor that can be used to see color changes is TCS3200, where this sensor can read the RGB value of an object. TCS3200 can be implemented to detect colors in the agricultural industry, or to provide color information for intelligent controls [5], TCS3200 can capture, process and manage the colors of non-luminous objects [6]. The use of TCS3200 in agriculture has been done to look at the
meat freshness level [7]; for color sorting by robot [8]; for sorting with conveyor systems [9]; for determining the color changes of guava [10]; and for the sortation development of orange fruit based on RGB using TCS3200 [11].

Digital image processing shows the processing of 2-dimensional images using a computer [2]. In this study, the design of digital imagery would be done automatically and this tool can be used in various places easily or portable. Automation of this tool uses Arduino Mega 2560 because it has a larger storage memory for storing databases and sensors TCS3200 instead of camera functions in digital image processing.

2. Materials and Method

2.1. Materials

This study designed a banana maturity detection tool based on the color of the fruit skin. Color of banana skin will be captured by the TCS3200 color sensor and gives a signal to Arduino 2560 then displays the aging level of bananas on the LCD. Banana samples used were bartin bananas with 4 levels of maturity (i.e. raw, unripe, ripe and overripe) each maturity consisting of 35 samples.

2.2. TCS3200 color sensor

TCS3200 programmable color sensor from light-color to frequency, and reading 8x8 photodiode arrays (Figure 1). In this tool the distance between the TCS3200 color sensor and the object is designed to be 3 cm.

![Figure 1. Color Sensor](image)

2.3. Arduino Mega 2560

Arduino Mega 2560 (Figure 2) has 54 digital input / output pins of which 15 can be used as PWM outputs, 16 analog inputs, 4 UARTs (hardware serial ports). In this research, Arduino programming used the Arduino IDE software application

![Figure 2. Arduino Mega 2560 Controller](image)

2.4. LCD

16x2 LCD on this device has a function as an output of information from the color reading (Figure 3) by the TCS 3200 color sensor that is connected to the Arduino Mega 2560.
2.5. Power supply

The power supply in this study uses a powerbank with a capacity of 5500 mAh (Figure 4), which produces an output of 5 V.

![Powerbank 5500 mAh](image)

2.6. Methods and design

The design of this tool is to assemble all the components into a system that can detect the color of bananas. All components are arranged according to the pin / port to be used (Figure 5). This system circuit works in the following way: TCS 3200 color sensor will read the RGB value of the object by reflecting LED light on the object, then the object will reflect the light to the photodiode mounted on the color sensor. Data received from the TCS 3200 color sensor will be processed by Arduino Mega 2560 with IDE software. The results of this will be displayed on the LCD 16x2 containing information from the results of the reading of the instrument on the object. The power supply needed is 5 V to start the device, so it can use a power bank with a capacity of 5500 mAh with an output of 5 V.

![Electronic system circuit](image)

The test was carried out by taking RGB color change values in 35 barlin bananas from the raw phase to the mature phase using an electronic circuit system that has been installed. Data retrieval is done twice with 12 hours intervals. The reading results are then summarized and to be used as a database on the tool using programming language. The performance tests used in this study are the percentage of success created by Pradita et al. [12].

\[
\text{the result (\%) = } \frac{\sum \text{identified data}}{\sum \text{banana data}} \times 100\%
\]  \(\text{(1)}\)
3. Results and Discussion

3.1. Design tools
In the process of making a tool, a design planning tool uses the AutoCAD 2015 software is carried out. The raw material for making 2mm acrylic black-dop material with the design of an economical tool in its use. The following figures are the results of the functional and structural design of the tools (Figure 6 and Figure 7).

![Figure 6. Back Side](image)
![Figure 7. Front side](image)

The parts and functions of the tool are as follows: (A) LCD 16x2 as output readings for maturity (B) Charging port as a place of the battery charger (C) Sensor TCS3200 as object reader (D) Power button to turn on the appliance. This tool weighs of 635 grams and it is very easy to be used. Test tool using bananas that will predict its maturity is to place bananas on the TCS3200 sensor (at point C Figure 7), while the results of the predicted maturity will appear at point A Figure 6.

3.2. Electronic system
The electronic system on the device uses several components: Arduino mega 2560, LCD 16x2, sensor TCS3200 and powerbank 5500 mAh. Automation system tools using Arduino Mega 2560 which is one type of microcontroller that can replace computer functions in work control [12]. This circuit system requires a voltage of 5V. As for the replacement of camera functions in the image processing system uses a TCS3200 sensor. The TCS3200 sensor is a module that has several photodetectors that can read colors, such as red, green and blue [13]. Thus, the output of the sensor reading TCS3200 is the result of the RGB value of the object displayed on the 16x2 LCD.

3.3. Testing of TCS3200 sensors
Tool calibration is to test the accuracy of the detection of RGB values on the tool using red, green and blue paper, by comparing the results of the RGB produced by the scanner engine. Tests are carried out to prove that the TCS3200 sensor can distinguish colors well. The test is done by comparing the results of reading using a scanner with the results of reading using sensors by using objects in the form of paper in red, green and blue. Where the readings are in the form of RGB values of each color paper tested. The following are the results of a comparison test in Table 1. The results can show that the TCS3200 sensor used is working properly. This is because the RGB value that is read has the same criteria as the results of the reading by the scanner.
Table 1. Results of reading RGB values by TCS3200 sensors and scanners

| Paper Color | Scanner  | TCS3200 sensors |
|-------------|----------|-----------------|
|             | R        | G    | B    | R    | G    | B    |
| Red         | 255      | 102  | 102  | 190  | 133  | 166  |
| Green       | 153      | 204  | 153  | 160  | 177  | 167  |
| Blue        | 51       | 153  | 255  | 59   | 146  | 198  |

3.4. Collecting RGB bananas database

Barlin banana is a type of banana that can be eaten without being cooked which has a sweet and sour taste [16]. The level of aging of bananas can be seen physically from the changes of their skin color from the raw green to mature yellow [2]. Bananas have 7 maturity indexes: raw, unripe, ripe, overripe, etc. as it is shown in Table 2 [17].

Table 2. Banana maturity index based on color

| Level | Picture of Fruits | Description | Maturity Level |
|-------|-------------------|-------------|----------------|
| 1     | ![Picture of Fruit](image1.png) | The Color is green, the fruit is still hard | Raw |
| 2     | ![Picture of Fruit](image2.png) | The color is green and a little yellow | Raw |
| 3     | ![Picture of Fruit](image3.png) | The color is green and yellow | Unripe |
| 4     | ![Picture of Fruit](image4.png) | The color is yellow and a little green | Unripe |
| 5     | ![Picture of Fruit](image5.png) | The color is dominant yellow and a little green | Ripe |
| 6     | ![Picture of Fruit](image6.png) | The color is yellow, the fruit is sweet | Ripe |
| 7     | ![Picture of Fruit](image7.png) | The color is yellow, but has brown spots and the fruit is sweet | Overripe |

In this study, from seven levels of maturity, bananas were divided into four maturity levels. The results of the R G B value of banana peels using a tool will be used as a database in determining the maturity of bananas (Table 3). The value of R G B obtained will be used as a barrier in determining the maturity level of bananas. Another relationship found for oranges is RGB = (R * 6 5 3 6) + (G * 2 5 6) + B [15].
Table 3. A database conclusion values at each banana maturity level

| Level | Database Conclusion Value | Maturity Level |
|-------|---------------------------|----------------|
| 1     | Value G > R               | Raw            |
| 3     | Value R > G, Value (R - G) < 9 and Value G ≥ 142 | Unripe |
| 5     | Value R > G, Value 9 ≤ (R - G) and G ≥ 142 | Ripe |
| 7     | Value R > G and Value 142 ≥ G | Overripe |

3.5. *Comparison of bananas fruit maturity with RGB value*

Observation data in the form of the RGB values from each phase of maturity of bananas with two repetitions every 12 hours once connected to a graph. RGB average value of the banana. RGB data is shown in Table 4. The data is graphed to show the results of the comparison between the maturity phase of bananas against their RGB values.

Table 4. The average value of the first data RGB from bananas maturity

| Maturity level | Information | R   | G   | B   |
|----------------|-------------|-----|-----|-----|
| 1              | Raw         | 143 | 159 | 145 |
| 3              | Unripe      | 148 | 151 | 146 |
| 5              | Ripe        | 163 | 154 | 150 |
| 7              | Overripe    | 154 | 139 | 143 |

In Table 4 it can be seen that the more ripe bananas, the R value will increase, the value of G decreases and the value of B fluctuates. The same thing happened to the value of the cavendis banana RGB index [4], the tomatoes were getting ripe as the G index dropped [16].

3.6. *Testing tools performance*

The results of testing tools performance obtain a value of 85% using a sample of banana 20 which has four levels of maturity phase. The amount of data identified is 17 bananas and the number of all bananas is 20. It shows that the system used can identify each maturity of bananas with a success rate of 85%. While in other studies that used the camera as a reader and with the same material has an accuracy value of 90% [14]. The value of the reading error occurs due to a deficiency in TCS3200 which only reads objects on one pixel.

4. Conclusions

Produced image processing circuit that can predict the maturity level of *barlin* banana (*Musa paradisiaca* L.) based on Arduino mega 2560 as a data processor and color sensor TCS3200 which can be used as a replacement for camera functions in image processing. The proposed design can be used automatically, simply and practically with small dimensions with a load of 635 grams. At each phase of maturity, bananas have different RGB values and move up from the raw phase to mature but move down from the mature phase to mature. The design performance test results of this tool using other bananas that have a random maturity of 20 pieces and obtained the performance test results of 85%. In the fruit export process, several criteria must be met, one of which is fruit maturity. with the results of this study can be used in post-harvest handlers in determining the maturity criteria of bananas easily and efficiently.

References
[1] Wardiyati T, Sugianto A, Nugroho A, Lamadji S, Mugiono 2004 Perbaikan sifat pisang kepok melalui mutasi buatan sinar gama: keragaman fase genetik (Improved Kepok banana traits through mutations made in gamma rays: genetic phase diversity) *J. Ilmu Hayati* 16 2 90-98.
[In Indonesian]

[2] Sutan S M, Hendrawan Y 2015 Aplikasi citra digital dan jaringan syaraf tiruan untuk pertanian (Applications of digital imagery and artificial neural networks for agriculture) CV. Nusantara

[3] Ireri D, Belal E, Okinda, Makange N, Ji C 2019 A computer vision system for defect discrimination and grading in tomatoes using machine learning and image processing Artific. Intel. Agric. 21 28-37.

[4] Sandra 2008 Kajian karakteristik sifat fisikokimia dan tingkat ketuaan buah pisang secara nondestruktif berbasis citra digital (Study of the characteristics of physicochemical characteristics and age level of bananas in a non-destructive way based on digital images) J. Tekn. Pertanian Andalas 12 35-40. [In Indonesian]

[5] Li Q, Yanling X, Wenlong Y, Junsheng H, Huan L 2014 Study on color analyzer based on the multiplexing of tcs3200 color sensor and microcontroller Int. J. Hybrid Inform. Technol. 7 5 167-174.

[6] Kumar S, Karthik D, Khanna P 2018 Development of a color detection and analyzing system Int. J. Res. Eng. Technol. 7 6 49-56.

[7] Rivai M, Budiman F, Purwanto D, Simamora J 2018 Meat freshness identification system using gas sensor array and color sensor in conjunction with neural network pattern recognition J. Theor. Appl. Inform. Techno. 96 12 3861-3872.

[8] Shigsawe A, Salunkhe A, Shigsawe K, Upadhye S Y 2017 Color sorting robot Int. J. Adv. R. Comp. Communic. Eng. 6 3 403-405.

[9] Kunlumphammed C K, Muhammed S K K, Sahna S, Gokul M S, Abdulla S U 2015 Automatic color sorting machine using tcs230 color sensor and pic microcontroller Int. J. R. Innov. Sci. Technol. 2 2 33-38.

[10] Filoteo R J D, Estudillo-Ayala J M, Hernandez-Garcia J C, Trejo-Duran M, Muñoz-Lopez A, Jauregui-Vazquez D, Rojas-Laguna R 2015 RGB color sensor implemented with leds Conf. Paper Proceed. SPIE - The Int. Soc. Optical Eng. 9571 1 33-38.

[11] Sihombing P, Tommy F, Sembiring S, Silitonga N 2019 The citrus fruit sorting device automatically based on color method by using tcs320 color sensor and arduino uno microcontroller J. Physics: Conf. Series 1235 1-6.

[12] Pradita G, Nabilah N, Islam H, Saputra D, Said S, Kurniawan A, Syafutra H, Neiman S, Irmaman 2016 Pembuatan prototipe sistem keamanan laboratorium berbasis arduino mega (Manufacture of prototype laboratory security systems based on Arduino Mega). Prosiding Seminar Nasional Fisika 2016 5 31-36. [In Indonesian]

[13] Mandari Y, Pangaribowo T 2016 Rancang bangun sistem robot penyortir benda padat berdasarkan warna berbasis arduino (Design and build a robot system for sorting solid objects based on arduino-based colors) J. Tek. Elek. 7 2 106-113. [In Indonesian]

[14] Siregar T, Harahap L, Rohana A 2015 Identifikasi kematangan buah pisang (Musa paradisiaca) dengan teknik jaringan syaraf tiruan (Identify the maturity of bananas (musa paradisiaca) with artificial neural network techniques) J. Rekayasa Pangan Pert. 3 2 261-265. [In Indonesian]

[15] Chakole V, Ilamkar P, Gajhiye R, Nagrale S 2019 Oranges sorting using arduino microcontroller (a review). Int. R. J. Eng. Techno. 6 2 1800-1802.

[16] Iftulinda, Sandra, Yulis R 2011 Prediksi tingkat kematangan buah tomat berbasis citra digital (Prediction of the ripeness of tomatoes based on digital images) J. Tekno. Pertanian Andalas 15 1 131-141. [In Indonesian]

[17] Indarto, Murinto 2017 Deteksi kematangan buah pisang berdasarkan fitur warna citra kulit pisang menggunakan metode transformasi ruang warna his (Detection of banana maturity based on the banana peel color feature using the HIS color space transformation method) JUITA 5 1 15-21. [In Indonesian]