Distance transform-watershed segmentation and multi-layer perceptron algorithm to separate touching orange fruit in digital images

I S Nasution*, C Keke

Agricultural Engineering Department, Universitas Syiah Kuala, Jalan Tgk. Hasan Krueng Kalee 3, Darussalam-Banda Aceh 23111, Indonesia

*Email: i.nasution@unsyiah.ac.id

Abstract. An algorithm to separate touching oranges using a distance transform-watershed segmentation is presented. In this study, there are four classes of oranges, such as class A, B, C, and D, respectively. The size of each class is based on the Indonesian National Standard (SNI), the sample used is 168 oranges of which 140 are for training and 28 oranges are for testing. The image of citrus fruits was captured using Kinect v2 camera with a camera resolution of 1920 x 1080 pixels, the distance from the camera to the background is 23 cm. The images were captured in PNG format. The watersheds were computed based on the distance transformed by orange regions. The corresponding basins were finally used to split the falsely connected corn kernel by intersecting the basins with the corn kernel regions. Experimental results show that the multi-layer perceptrons have classification accuracy rates of 92.85%. The algorithm appears to be robust enough to separate most of the multiple touching scenarios.

1. Introduction
Orange fruit is a substantial commodity in Indonesia. The traditional treatment on orange classification mainly relies on human eyes, which has the drawback of laborious, ineffectiveness, and high inaccuracy rate. As a result, it is difficult to meet the demand for large quantities of production using modern agriculture. Developing a rapid and effective method for assessing orange quality has a major impact on the fruit commodity. Machine vision technology, as a new classification technology, can increase the level of automation of agricultural production recognition. Some studies have been performed using machine vision for quality classification detection of rice [1,2], barley [3], corn [4], and other grains [5].

A distance transformation is defined as an operation that converts a binary image to an image where each element has a value that approximates the distance to the nearest feature element [6]. Whereas, watershed segmentations compute catchment basins and ridgelines which are also known as watershed lines, where catchment basins correspond to image regions and watershed lines correspond to the region boundaries [7]. Some studies have used watershed methods for corn, Grift et al. studied a vision system to count the number of corn kernels of a maize ear using area threshold and local Otsu threshold [8]. Liu et al. improved the watershed algorithm with morphological multi-scale...
decomposition to separate rice kernels [9]. Belan et al. developed a marker-controlled watershed algorithm based on Euclidean Distance Transform (EDT) [10]. The current study aims to apply distance transform-watershed segmentation and multi-layer perceptrons algorithms to separate touching oranges in digital images.

2. Materials and methods

2.1. Orange samples
A number of 168 oranges (*Citrus sinensis* Osbeck) were collected from farmers, which were divided into 140 samples for training and 28 samples for testing, respectively. The samples were categorized into four diameters according to the Indonesian National Standard (class A: ≥70 mm, class B: 61-70 mm, class C: 51-60 mm, and class D: 40-50 mm).

2.2. Image acquisition
The images of citrus fruits were captured using Kinect v2. The position of the camera is placed perpendicular to the object, the distance between the camera and the background is 230 mm, and the background used in taking the image of citrus fruits is white.

2.3. Image segmentation
Oranges and background objects were separated based on L*a*b* color space and Otsu’s thresholding method [11]-[12]-[13]. The Otsu thresholding used a bimodal intensity histogram in order to find an optimal threshold for binarizing an image. The unwanted small objects (noise) removed to increase the separation system.

2.4. Features extraction (diameter, area, perimeter, Compactness, circularity)
Some shape features such as diameter, area, perimeter, Compactness, and circularity are extracted to describe a given object, and used as input layers for multilayer perceptron algorithms. The diameter is calculated based on the maximal distance between two boundary points of the orange region. The area calculated based on the number of pixels in a shape. The perimeter is the number of pixels in the boundary of the object. If $X_1, \ldots, X_n$ is a boundary list, the perimeter is followed by:

$$Perimeter = \sum_{i=1}^{N-1} d_i = \sum_{i=1}^{N-1} |X_i - X_{i+1}|$$  \hspace{1cm} (1)

The distance $d_i$ is equal to 1 for 4-connected boundaries and 1 or $\sqrt{2}$ for 8-connected boundaries.

Compactness is the shape factor of the orange region. The shape factor of a circle is one. If L is the length of the orange contour and F the area of the orange, the compactness defined as:

$$Compactness = \frac{L^2}{4F \pi}$$  \hspace{1cm} (2)

The circularity measures the ratio of the area of an object to the area of a circle with the same convex perimeter. The result is equal to 1 for a circular object and less than 1 for an object that departs from circularity.

$$Circularity = \frac{4\pi * Area}{Convex \ perimeter^2}$$  \hspace{1cm} (2)
2.5. Classification
In certain conditions, a classification with single-layer neural nets is not sufficient in many classification applications. In order to solve this problem, more layers or hidden layers should be improved to the net. The obtained multi-layer neural net or multi-layer perceptron (MLP) consists of input layers, several hidden layers and output layers (see figure 1). Whereas, the MLP utilizes a supervised learning technique called back propagation for training.

\[ f(x) = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}} \]  \hspace{1cm} (4)

The output layer used softmax activation function, as follows:

\[ f(x) = \frac{e^{x_i}}{\sum_{j=1}^{n} e^{x_j}} \]  \hspace{1cm} (5)

The Multi-Layer Perceptron (MLP) is a network consisting of a number of neurons connected by weights connecting the neurons arranged in layers consisting of input layers, hidden layers, and output layers). The number of nodes in the input layer is five such as diameter, area, perimeter, compactness, and circularity. The output layer consists of four classes namely class A, class B, class C and class D.

3. Results and discussion
There are two segmentation processes in this study; the first is the distance transform process, which is used to calculate the distance of each foreground pixel or the nearest non-zero pixel. The second segmentation process, the watershed segmentation process, creates a boundary between one object and another that is in contact or coincides with each other. The resulting image of both distance transform and watershed segmentation is shown in figure 2.

\[ f(x) = \frac{e^{x_i}}{\sum_{j=1}^{n} e^{x_j}} \]  \hspace{1cm} (5)

The Multi-Layer Perceptron (MLP) is a network consisting of a number of neurons connected by weights connecting the neurons arranged in layers consisting of input layers, hidden layers, and output layers). The number of nodes in the input layer is five such as diameter, area, perimeter, compactness, and circularity. The output layer consists of four classes namely class A, class B, class C and class D.

3. Results and discussion
There are two segmentation processes in this study; the first is the distance transform process, which is used to calculate the distance of each foreground pixel or the nearest non-zero pixel. The second segmentation process, the watershed segmentation process, creates a boundary between one object and another that is in contact or coincides with each other. The resulting image of both distance transform and watershed segmentation is shown in figure 2.
The image extraction stage is carried out after the image segmentation stage using distance transform and watersheds segmentation. Where, image extraction aims to extract features or information from the orange images, which is used as an input value to classify oranges based on their respective classes. The result of the calculation of diameter, area, perimeter, compactness and circularity of the oranges is shown in Table 1.

### Table 1. Features image data of orange based on different classes.

| Features           | Kelas | Class A | Class B | Class C | Class D |
|--------------------|-------|---------|---------|---------|---------|
| Diameter (pixel)   | Maximum | 447,335 | 351,2   | 321,418 | 252,837 |
|                    | Minimum | 348,053 | 253,314 | 248     | 189,5   |
|                    | Mean    | 358,74  | 321,58  | 276,72  | 225,91  |
| Area (pixel)       | Maximum | 141002  | 100001  | 80001   | 60180   |
|                    | Minimum | 97513   | 60000   | 40000   | 21397   |
|                    | Mean    | 120002  | 79959,94| 60194,43| 40000,63|
| Perimeter (pixel)  | Maximum | 1374,39 | 1182,21 | 1000    | 819,07  |
|                    | Minimum | 1085,45 | 866,30  | 710,12  | 596,43  |
|                    | Mean    | 1211,21 | 1000,35 | 869,55  | 709,38  |
| Compactness (pixel)| Maximum | 12,57   | 12,58   | 12,54   | 12,59   |
|                    | Minimum | 12,54   | 12,43   | 12,44   | 12,45   |
|                    | Mean    | 12,54   | 12,52   | 12,49   | 12,52   |
| Circularity (pixel)| Maximum | 0,91    | 0,91    | 0,92    | 0,95    |
|                    | Minimum | 0,86    | 0,86    | 0,86    | 0,86    |
|                    | Mean    | 0,87    | 0,89    | 0,89    | 0,88    |

Diameter of each class: class A: ≥70 mm, class B: 61-70 mm, class C: 51-60 mm, and class D: 40-50 mm

In the Multi-layer Perceptron (MLP) method, the input layer consists of five nodes consisting of diameter, area, perimeter, compactness, and roundness features. The hidden layer is 10 nodes, and the output layer is four nodes, namely classes A, B, C, and D. This method is expected to be able to classify oranges based on their respective classes. The results of the percentage of success on the features used and the combination of several features used are shown in Table 2.

### Table 2. Successful classification of oranges data training based on a combination of several features.

| No. | Features        | Successful classification (%) |
|-----|-----------------|-------------------------------|
|     |                 | A    | B    | C    | D    | Mean |
| 1   | Area            | 100  | 91.42| 94.28| 100  | 96.42|
| 2   | Diameter        | 100  | 91.42| 94.28| 100  | 96.42|
| 3   | Perimeter       | 100  | 91.42| 94.28| 100  | 96.42|
| 4   | Compactness     | 48,57| 17,14| 60   | 37,14| 40.71|
| 5   | Circularity     | 34,28| 42,85| 28,57| 42,85| 37.14|
| 6   | Area, diameter  | 100  | 91.42| 97,14| 100  | 97.14|
| 7   | Area, perimeter | 100  | 91.42| 94.28| 100  | 96.42|
| 8   | Area, compactness| 100  | 97.14| 100  | 100  | 99.28|
The number of hidden layers also affects the level of accuracy in the classification of oranges using the Multi-layer Perceptron (MLP) method. Hidden layer is a layer that functions to receive data from the output layer and process the data. According to Nasution and Gusriyan [14], the hidden layer is part of the Multi-layer Perceptron (MLP) method which functions as a place for processing data from the input layer and then produces an output layer in the form of classification. It can be seen in table 3 levels of accuracy with different hidden layers in the citrus classification process using the Multi-layer Perceptron (MLP) method.

| Hidden layers number | Area, circularity | Area, diameter, perimeter | Area, diameter, compactness | Area, diameter, circularity | Diameter, perimeter, compactness | Diameter, perimeter, circularity | Perimeter, compactness, circularity | Area, compactness, circularity | Area, diameter, perimeter, compactness | Area, diameter, perimeter, circularity | Area, diameter, perimeter, compactness | Diameter, perimeter, compactness, area | Compactness, circularity, area, diameter, perimeter |
|----------------------|-------------------|---------------------------|----------------------------|---------------------------|---------------------------------|---------------------------------|----------------------------------|-------------------------------|------------------------------------------|----------------------------------------|----------------------------------------|------------------------------------------|------------------------------------------|
| 9                    | 100               | 94.28                     | 97.14                      | 100                       | 97.85                           | 96.42                           | 98.57                            | 96.42                          | 98.57                                    | 99.28                                  | 99.28                                  | 99.28                                   | 99.28                                   |
| 10                   | 100               | 91.42                     | 94.28                      | 100                       | 96.42                           | 98.57                           | 99.28                            | 99.28                          | 99.28                                    | 99.28                                  | 99.28                                  | 99.28                                   | 99.28                                   |
| 11                   | 100               | 97.14                     | 97.14                      | 100                       | 98.57                           | 97.85                           | 99.28                            | 99.28                          | 99.28                                    | 99.28                                  | 99.28                                  | 99.28                                   | 99.28                                   |
| 12                   | 100               | 91.42                     | 94.28                      | 100                       | 96.42                           | 98.57                           | 99.28                            | 99.28                          | 99.28                                    | 99.28                                  | 99.28                                  | 99.28                                   | 99.28                                   |
| 13                   | 100               | 94.28                     | 97.14                      | 100                       | 97.85                           | 96.42                           | 98.57                            | 96.42                          | 98.57                                    | 99.28                                  | 99.28                                  | 99.28                                   | 99.28                                   |
| 14                   | 100               | 91.42                     | 94.28                      | 100                       | 96.42                           | 98.57                           | 99.28                            | 96.42                          | 98.57                                    | 99.28                                  | 99.28                                  | 99.28                                   | 99.28                                   |
| 15                   | 100               | 100                       | 94.28                      | 100                       | 99.28                           | 99.28                           | 100                              | 99.28                          | 99.28                                    | 99.28                                  | 99.28                                  | 99.28                                   | 99.28                                   |
| 16                   | 100               | 97.14                     | 100                        | 100                       | 99.28                           | 99.28                           | 100                              | 99.28                          | 99.28                                    | 99.28                                  | 99.28                                  | 99.28                                   | 99.28                                   |
| 17                   | 100               | 94.28                     | 97.14                      | 100                       | 97.85                           | 96.42                           | 98.57                            | 96.42                          | 98.57                                    | 99.28                                  | 99.28                                  | 99.28                                   | 99.28                                   |
| 18                   | 100               | 94.28                     | 97.14                      | 100                       | 97.85                           | 96.42                           | 98.57                            | 96.42                          | 98.57                                    | 99.28                                  | 99.28                                  | 99.28                                   | 99.28                                   |
| 19                   | 100               | 97.14                     | 97.14                      | 100                       | 98.57                           | 96.42                           | 98.57                            | 96.42                          | 98.57                                    | 99.28                                  | 99.28                                  | 99.28                                   | 99.28                                   |
| 20                   | 100               | 97.14                     | 100                        | 100                       | 99.28                           | 99.28                           | 100                              | 99.28                          | 99.28                                    | 99.28                                  | 99.28                                  | 99.28                                   | 99.28                                   |

Based on table 4, the results of the percentage of success in testing program performance are 92.85% from a sample of 26 oranges, where there are 26 oranges that were successfully detected according to class and 2 numbers of oranges were not detected according to class, namely class A but detected as class B and class B. but detected as class C, this is because the orange shape is not uniform or not perfectly round.
Table 4. Classification results of orange using multilayer perceptron (MLP).

| Sample number | Successful Sample number | Successful % | Unsuccessful Sample number | Unsuccessful % |
|---------------|--------------------------|--------------|----------------------------|----------------|
| 28            | 26                       | 92.85        | 2                          | 7.14           |

4. Conclusions

The computer vision techniques using multi-layer perceptron (MLP) were investigated in order to classify oranges based on the Indonesian national standard. Citrus separation using distance transform and watersheds segmentation methods achieved with an accuracy rate of 100%. The MLP method is able to detect 92.85% of orange fruit. The computer vision technology can be used to classify oranges based on size using the Multi-Layer Perceptron (MLP) method.

References

[1] Chen S, Xiong J, Guo W, Bu R, Zheng Z, Chen Y, Yang Z and Lin R 2019 Colored rice quality inspection system using machine vision J. Cereal Sci. 88 87–95
[2] Gayathri Devi T, Neelamegam P and Sudha S 2018 Machine vision based quality analysis of rice grains IEEE Int. Conf. Power, Control. Signals Instrum. Eng. ICPCSI 2017 1052–5
[3] Szczypiński P M, Klepaczko A and Zapotoczny P 2015 Identifying barley varieties by computer vision Comput. Electron. Agric. 110 1–8
[4] Wang R, Han F, Jin Y and Wu W 2020 Correlation between moisture content and machine vision image characteristics of corn kernels https://doi.org/10.1080/10942912.2020.1720715 23 319–28
[5] Vithu P and Moses J A 2016 Machine vision system for food grain quality evaluation: A review Trends Food Sci. Technol. 56 13–20
[6] Borgefors G 1984 Distance transformations in arbitrary dimensions Comput. Vision, Graph. Image Process. 27 321–45
[7] Roerdink J B T M and Meijster A 2000 The watershed transform: definitions, algorithms and parallelization strategies Fundam. Informaticae 41 187–228
[8] Grift T E, Zhao W, Momin M A, Zhang Y and Bohn M O 2017 Semi-automated, machine vision based maize kernel counting on the ear Biosyst. Eng. 164 171–80
[9] Liu Z and Yan L 2011 Improved algorithm of separation and identification of touching kernels and foreign materials in digital images Adv. Intell. Soft Comput. 122 89–94
[10] Belan P A, Macedo R A G de, Pereira M M A, Alves W A L and Araújo S A de 2018 A Fast and Robust Approach for Touching Grains Segmentation Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics) 10882 LNCS 482–9
[11] Otsu N 1979 A Threshold Selection Method from Gray-Level Histograms IEEE Trans. Syst. Man. Cybern. 9 62–6
[12] Nasution I S 2017 Non-Destructive Measurement for Estimating Leaf Area of Bellis perennis Rona Tek. Pertan. 10 58–64
[13] Nasution I S 2018 Technical optimization of a laser marking process of banana fruits and poinsettia bracts (Gottfried Wilhelm Leibniz Universität Hannover)
[14] Nasution I S and Gusriyan K 2019 Nutmeg grading system using computer vision techniques IOP Conf. Ser. Earth Environ. Sci. 365 012003