Image based indonesian fruit recognition using MPEG-7 color structure descriptor and k-nearest neighbor

J Siswantoro, H Arwoko and M Widiasri

Department of Informatics Engineering, Universitas Surabaya, Jl. Kalirungkut, Surabaya, 60293, Indonesia

joko_siswantoro@staff.ubaya.ac.id

Abstract. Image based fruit recognition can be applied in several sectors including food industry, food retail, and medical. This paper proposes a method to recognize Indonesian fruit from image. The method uses MPEG-7 Color Structure Descriptor (CSD) as input features to k-nearest neighbor classifier. CSD describes the local color structure of image in HMMD (Hue, Max, Min, and Difference) color space. In this study, the numbers of features extracted from a fruit image were 32, 64, 128, and 256. A simple feature selection method based on variance has been applied to reduce the dimension of input features and to increase classification performance. A feature with variance less than predefined threshold was excluded from feature space. Three hundred and fifty images from seven types of Indonesian fruit have been used to validate the proposed method using 10-fold cross validation. The experimental result showed that the best classification accuracy of 90.86% was achieved using 256 features of CSD combined with feature selection.

1. Introduction

Fruit recognition from image is an alternative to traditional recognition method [1]. It can be found in various field, such as food industry, food retail, as well as medical [2]. Generally, the steps of fruit recognition from image consist of image acquisition, segmentation, feature extraction and classification. Although fruit image was captured with a same background, several study in fruit recognition from image still employed segmentation step to separate fruit object from its background such that the extracted feature only come from fruit object [2-5]. On the other hand, segmentation step can increase computational time.

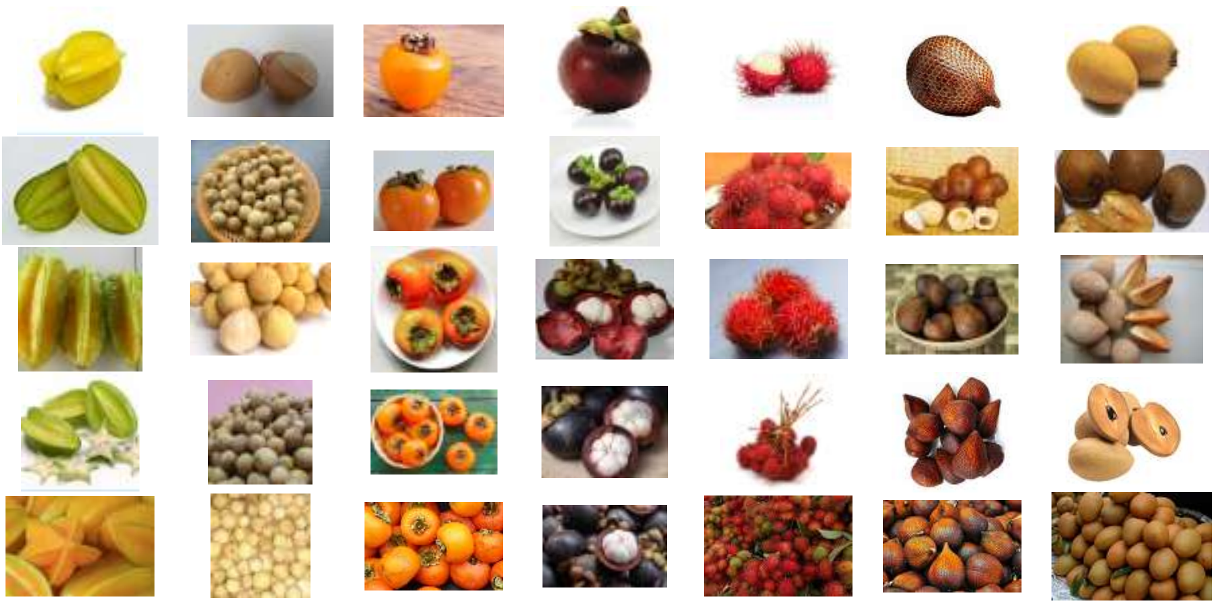
Siswantoro, et al. [2], Garcia, et al. [3], Prabuwono, et al. [4], and Koslowski, et al. [6] have proposed a method to recognize natural produce, including fruit, from image. Although the proposed methods achieved a good accuracy, the methods only recognized fruit image containing single object. The other researchers have proposed natural produce recognition from image with multiple objects in one image using the combination of several features and complex classifiers fusion [5, 7, 8]. However, extracting several features and training complex classifiers fusion is a time-consuming process. Convolutional neural network (CNN) was also used in fruit recognition from image [1, 9]. However, the training process of CNN requires not only a computer with high specification but also time-consuming.

According to Uji [10], there are more than 200 edible fruits that grow in Indonesia. Furthermore, there are many types of Indonesian fruits currently sold at supermarket. Based on these facts, there is a chance to apply Indonesian fruits recognition from image for fruit pricing at supermarket cashier. In the previous studies, the fruit samples used in fruit recognition from image were not specific fruits from Indonesia. In addition, there are several kinds of Indonesian fruits that have similar color, shape, and texture that were not found in fruit dataset used in previous studies. Therefore, there is a need to develop a method to recognize Indonesian fruits from image that can be applied for fruit sale. This paper proposes an image based Indonesian fruit recognition method using MPEG-7 Color Structure Descriptor (CSD) dan *k*-nearest neighbor classifier. CSD features represent the color structure and color distribution of image that can be directly extracted from image without segmentation process [11]. A variance based feature selection is used to reduce the dimension of CSD as well as to obtain higher recognition performance [12]. The rest of the paper is organized as follow. Section 2 describes the materials used in experiment and explains the steps in the proposed method. Experimental setup is explained in Section 3. Result and discussion are provided in Section 4 and conclusion is drawn in Section 5.

2. Materials and method

2.1. Materials

A fruit image dataset containing seven classes Indonesian fruits, including belimbing (start fruit, *Averrhoa carambola*), duku (*Lansium domesticum*), kesemek (persimmon, *Diospyros kaki*), manggis (mangosteen, *Garcinia mangostana*), rambutan (*Nephelium lappaceum*), salak (*Salacca zalacca*), and sawo (*Manilkara zapota*), was used to validate the proposed method. The dataset was collected from Google Images using keyword “belimbing”, “duku”, “kesemek”, “manggis”, “rambutan”, “salak”, and “sawo”. Every fruit class contained 50 fruit images in RGB (Red, Green, Blue) and saved in PNG (Portable Graphics Format) file. Totally, there were totally 350 fruit images in the dataset. The images in the dataset varied in size, the number of fruits, background color, and brightness. The size of image varied ranging from 201,600 pixels until 1,920,000 pixels. The number of fruits in an image also varied from one fruit until all area in the image covered by fruits. In general, almost all fruit images were captured in white background. However, there were some images captured in different background color. Furthermore, some fruits ware placed on a plate during image acquisition. Figure 1 shows the examples of image fruit in the dataset.



(a) (b) (c) (d) (e) (f) (g)

Figure 1. The examples of image fruit in the dataset: (a) belimbing, (b) duku, (c) kesemek, (d) manggis, (e), rambutan, (f) salak, and (g) sawo.

The proposed method was implemented in an Intel® Core™ i7-8550U CPU @ 1.80GHz 2.00 GHz with Windows 10 Pro 64-bit Operating System, x64-based processor and 8 GB RAM. Python 3.7.3

programming language was used to implement the proposed method with an open source computer vision library OpenCV 2.3.1 [13] for image processing and a machine learning library scikit-learn 0.20.3 [12] for classification. In addition, the proposed method also employed MPEG-7 Low Level Feature Extraction Static/Dynamic Library [14] to extract MPEG-7 CSD features.

2.2. Proposed method

The proposed Indonesia fruit recognition method comprised a series of steps started with features extraction followed by feature selection, and classification. The detail of every step is explained in the following sub sections.

2.2.1. Features extraction. In this step MPEG-7 CSD features were extracted directly from a fruit image without pre-processing and segmentation steps. CSD features describe the local color structure and color distribution of an image extracted in HMMD (Hue, Max, Min, Diff) color space. The values of Max, Min, Diff, and Hue were obtained from R, G, B values in RGB color space using equations (Error! Bookmark not defined.), (Error! Bookmark not defined.), (Error! Bookmark not defined.), and (Error! Bookmark not defined.) respectively [11].

$$Max = \max(R, G, B) \#(\text{Error! Bookmark not defined.})$$

$$Min = \min(R, G, B) \#(\text{Error! Bookmark not defined.})$$

$$Diff = Max - Min \#(\text{Error! Bookmark not defined.})$$

$$Hue = \begin{cases} 0, Max = Min \\ \dfrac{60(G-B)}{Diff}, Max = R \,\&\, G \geq B \\ 360 + \dfrac{60(G-B)}{Diff}, Max = R \,\&\, G < B \\ \dfrac{60(2+B-R)}{Diff}, Max = G \\ \dfrac{60(4+R-G)}{Diff}, othewise \end{cases} \#(\text{Error! Bookmark not defined.})$$

Suppose M is the number of nonuniformly quantization of HMMD color space. CSD features were constructed by sliding an 8×8 structuring element to every position in the image to obtain an M-bin histogram by calculating the number of colors $c_i, i = 1,2, \dots, M$ covered by the structuring element. This procedure resulted CSD features of length M. The values of M used in the proposed method were 32, 64, 128, and 256.

2.2.2. Feature selection. Feature selection is a process to exclude unimportant feature(s) from feature space. The purposes of feature selection are to reduce the dimension of feature space as well as to increase classification performance [15, 16]. A simple statistical based feature selection method called low variance feature selection [12, 16] was used in the proposed method to find the most important features for fruit image classification. Features with variance less than a certain threshold value were omitted from feature space. The value of threshold was heuristically determined during experiment in the range of $[50,1050]$ with increasing of 50, such that higher classification accuracy is achieved.

2.2.3. Classification. The proposed method employed *k*-nearest neighbour (*k*-NN) to recognize a fruit image based on CSD feature. *k*-NN is a simple classifier that work by classifying an unknown input data to a class which has highest number of objects among the *k* training data in the neighbor of input data [15]. Suppose $\mathbf{f}$ is CSD feature extracted from unknown input image, and $\mathbf{f}_1, \mathbf{f}_2, \dots, \mathbf{f}_\mathrm{n}$ are CSD features extracted from n training data. The following steps were used to classify an unknown input image using *k*-NN.

- Calculate the distance between $\mathbf{f}$ and $\mathbf{f}_1, \mathbf{f}_2, \dots, \mathbf{f}_\mathrm{n}$ namely $\mathrm{d}(\mathbf{f}, \mathbf{f}_1), \mathrm{d}(\mathbf{f}, \mathbf{f}_2), \dots, \mathrm{d}(\mathbf{f}, \mathbf{f}_\mathrm{n})$, respectively. The proposed method used Euclidean distance to measure the distance between two features. Euclidean distance between $\mathbf{f} = (\mathrm{f}_1, \mathrm{f}_2, \dots, \mathrm{f}_\mathrm{M})$ and $\mathbf{f}_\mathrm{i} = (\mathrm{f}_{\mathrm{i}1}, \mathrm{f}_{\mathrm{i}2}, \dots, \mathrm{f}_{\mathrm{iM}})$, for $\mathrm{i} = 1,2, \dots, \mathrm{n}$, is calculated using equation (5).

$$d(\boldsymbol{f}, \boldsymbol{f}_i) = \left(\sum_{j=1}^{M} \left(f_j - f_{ij}\right)^2\right)^{\frac{1}{2}} \#(5)$$

- Choose k smallest distances and arrange the distances from smallest to larger to obtain $\{\mathbf{f}_{\mathrm{i}_1}, \mathbf{f}_{\mathrm{i}_2}, \dots, \mathbf{f}_{\mathrm{i}_\mathrm{k}}\}$ with $\mathrm{d}(\mathbf{f}, \mathbf{f}_{\mathrm{i}_1}) \leq \mathrm{d}(\mathbf{f}, \mathbf{f}_{\mathrm{i}_2}) \leq \cdots \leq \mathrm{d}(\mathbf{f}, \mathbf{f}_{\mathrm{i}_\mathrm{k}}) \leq \mathrm{d}(\mathbf{f}, \mathbf{f}_{\mathrm{i}_{\mathrm{k}+1}}) \leq \cdots \leq \mathrm{d}(\mathbf{f}, \mathbf{f}_{\mathrm{i}_\mathrm{n}})$.
- Assign the input image to a class *c* such that $\{\mathbf{f}_{\mathrm{i}_1}, \mathbf{f}_{\mathrm{i}_2}, \dots, \mathbf{f}_{\mathrm{i}_\mathrm{k}}\}$ majority containing the features of training images from class *c*.

In this study, the value of *k* was also heuristically determined during experiment in the range of [1,10], such that higher classification accuracy is achieved.

3. Experimental setup

An experiment has been performed to validate the proposed fruit image recognition method with two experiment scenarios. In the first scenario, *k*-NN classifier was trained and tested using full length CSD features extracted from fruit image, while in the second scenario the feature selection was performed to CSD features before used to train and test *k*-NN classifier. In both scenarios, stratified 10-fold cross validation [15] was employed to measure the performance of *k*-NN classifier. The fruit image dataset was partitioned into 10 mutually exclusive subsets having same cardinality using stratified random sampling without replacement, such that every subset has the number of fruit images from every class with same proportion. In training and testing *k*-NN classifier, nine subsets (315 images) were used as training dataset and the remaining (35 images) as testing dataset. The training and testing processes were repeated 10 times such that every subset is used as testing dataset once.

On i^{th} testing process, the accuracy of *k*-NN classifier was measured using equation (Error! Bookmark not defined.),

$$Accuracy_i = \frac{\#\, correclly\ classified\ fruit\ image\ in\ i^{th}\ testing\ dataset}{\#\, fruit\ image\ in\ i^{th}\ testing\ dataset} \times 100\% \#(\text{Error! Bookmark not define}$$

for $i = 1,2, \dots, 10$. The final accuracy of *k*-NN classifier was obtained by calculating the average of $Accuracy_i, i = 1,2, \dots, 10$. For further analysis, the confusion matrix [17] of *k*-NN classifier was also determined to analyze the performance of *k*-NN classifier in every class.

4. Result and discussion

The classification accuracy of *k*-NN classifier in the various value of *k* with the first experiment scenario is depicted in Figure 2. As can be seen in Figure 2 the highest classification accuracy was obtained at $k = 1$ for all CSD features. For $k = 1$, *k*-NN classifier achieved highest classification of 84.86% when trained using CSD256 compared to CSD128 (81.71%), CSD64 (80.57%) and CSD32 (73.71%). For $2 \leq k \leq 10$, the classification accuracy of *k*-NN classifier fluctuated between 67% and 81%, with highest accuracy was still achieved when trained using CSD256. This can happen since the more CSD features are extracted, the more detail the color structure used in classification.

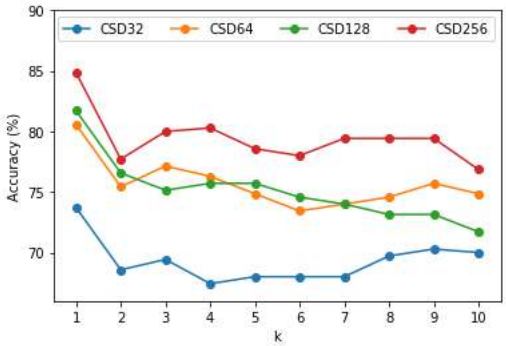


Figure 2. The classification accuracy result with the first experiment scenario.

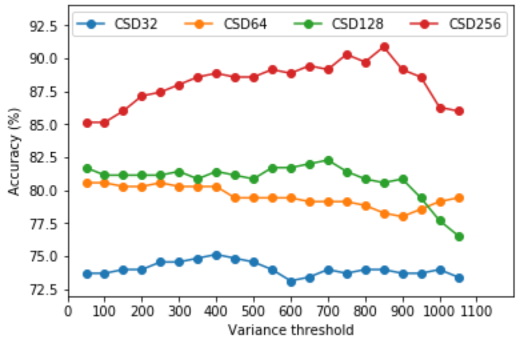


Figure 3. The classification accuracy result with the second experiment scenario

Figure 3 shows the classification accuracy with the second experiment scenario. In this scenario k-NN classifier used $k = 1$ and was trained using CSD combined with low variance feature selection. As can be seen in Figure 3, the highest classification accuracy of 90.86% was achieved when k-NN classifier trained using CSD256 and low variance feature selection with threshold value of 850. For CSD128, CSD64, and CSD 32, the highest classification accuracy of 82.29%, 80.57%, and 75.14% were obtained when combined with low variance feature selection with threshold value of 700, 50, and 400, respectively. This result shows that by employing low variance feature selection, the classification accuracy is increased except for CSD64. For CSD256, low variance feature selection could increase the classification accuracy of k-NN classifier by 6% and could reduce the dimension of CSD256 up to 89.45% (from 256 to 27). Furthermore, low variance feature selection could reduce average training time from 77.45ms to 50.11ms.

The normalized confusion matrix of k-NN classifier $(k = 1)$ trained with CSD256 combined with low variance feature selection for every class is depicted in Figure 4. The diagonal elements of confusion matrix in Figure 4 represent the percentage of fruit images that can be correctly recognized (recognition rate) for every class. The highest recognition rate of 96% was achieved in 1^{st} class (belimbing), followed by 4^{th} class (manggis) 92%, 5^{th} class (rambutan) 92%, 6^{th} class (salak) 90%, 7^{th} class (sawo) 90%, 2^{nd} class (duku) 88%, and 3^{rd} class (kesemek) 88%. The element in i^{th} row and j^{th} column, for $i \neq j$, represents the percentage of fruit images in i^{th} class recognized as j^{th} class (misrecognition rate). For 1^{st} class there were 4% of fruit images recognized as 3^{rd} class. For 2^{nd} class there were 2% fruit image recognized as 3^{rd} class and 10% as 7^{th} class. For 3^{rd} class there were 4% fruit images recognized as 1^{st} class, 2% as 2^{nd} class, and 6% as 7^{th} class. For 4^{th} class there were 2% fruit image recognized as 5^{th} class and 6% as 6^{th} class. For 5^{th} class there were 2% fruit image recognized as 3^{rd} class and 6% as 4^{th} class. For 6^{th} class there were 4% fruit images recognized as 4^{th} class, 4% as 5^{th} class, and 2% as 7^{th} class. For 7^{th} class there were 8% fruit image recognized as 2^{nd} class and 2% as 3^{rd} class. The misrecognition occurred since the color of some fruit from a class is similar to the color of fruit from other class. Therefore, the using of other MPEG-7 descriptors can be considered to reduce misrecognition rate in the next study.

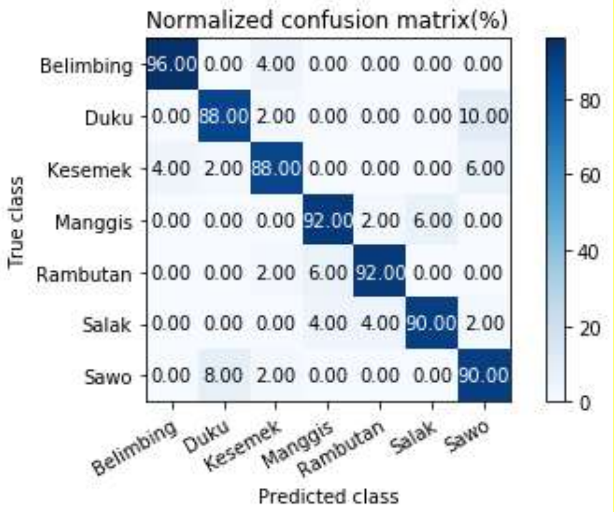


Figure 4. The Confusion matrix of *k*-NN classifier $(k = 1)$ trained with CSD256 combined with low variance feature selection

For comparison, the proposed method was also employed to classify natural produce images dataset used by Siswantoro, et al. [2] . The dataset consists of 10 classes including red delicious apple, green apple, potato, orange, tomato, mango, egg, pear Ya, pear Peckham, and carrot. The proposed method achieved the classification accuracy of 95.20% in classifying natural produce images the dataset. In previous study, Siswantoro, et al. [2] extracted 16 features from each natural produce image. The features consisted of 12 statistical color features, including mean, standard deviation, skewness, and kurtosis in HSV color space; and four shape features from the derivative of radius function. The classification accuracy of 77.40% was obtained using *k*-NN classifier. This result indicates that the proposed method outperforms the classification result of previous study.

In term of computational time, the proposed method needed about 45ms to extract CSD features from a fruit image. For recognizing a fruit image based on extracted CSD features the proposed method needed 0.98ms. Therefore, the total time needed to recognize a fruit image was 45.98ms. This result shows that there is a possibility to apply the proposed method for identifying the type of fruit during pricing at supermarket cashier.

5. Conclusion

This study proposes a method to recognize Indonesian fruits from image. The proposed method employed MPEG-7 CSD features with the length of 32, 64, 128 and 256 as input for *k*-NN classifier to recognize the class of fruit image. Low variance feature selection was also applied to CSD features before used by *k*-NN classifier to reduce the dimension of features space and to increase the classification accuracy. The proposed method has been validated using 350 Indonesian fruit images from seven classes. The highest classification accuracy of 90.86% was obtained by using *k*-NN classifier with CSD256 combined with low variance feature selection. The using of feature selection could reduce the dimension of features space up to 89.45% and increase classification accuracy by 6%. Future study will be focused on the developing of Indonesian fruit images dataset and the investigation of other MPEG-7 descriptors and other simple classifiers to recognize fruit images in the developed dataset.

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incite.ubaya.ac.id

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UNIVERSITAS SURABAYA
Jl. Raya Kalirungkut
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Preface

Welcome Remarks,
Chair of the Steering Committee

It is a great pleasure to welcome all of you to Bali and to the International Conference on Informatics, Technology, and Engineering 2019 (InCITE 2019) held by the Faculty of Engineering, University of Surabaya (UBAYA) in collaboration with The University of Adelaide, Australia and Sirindhorn International Institute of Technology (Thammasat University), Thailand. The first InCITE has been successfully held in Bali, Indonesia in 2017. We are very delighted to host the second InCITE here in Bali, Indonesia again.

There are more than 75 presentations in this conference. We welcome leading experts not only from Indonesia, but also from different parts of the world. The experts will share the knowledge and experiences in the fields of informatics, technology, science, and engineering. The main theme of this conference is **Enhancing Engineering Innovation Towards A Greener Future** in response to several world challenges including sustainable development, global convergence of information and communications technologies, climate change and global warming as well as the depletion of unrenewable natural resources. We hope this conference will provide you a good opportunity to get to know each other better and consolidate bonds of friendship and mutual trust.

We would like to express our sincere gratitude to the Keynote and Plenary speakers, International Scientific Committee, Steering Committee, and Organising Committee for their huge efforts to make this conference successful.

Thank you all for your support and attendance at InCITE 2019. Please enjoy the conference and Bali !

Asst. Prof. Djuwari, Ph.D.

Preface

Welcome Remarks, Chair of The Organizing Committee

Welcome to Bali, Indonesia to all delegates and presenters. It is my pleasure and privilege to welcome all of you to the 2nd (second) International Conference on Informatics, Technology, and Engineering 2019 (InCITE 2019) held by the Faculty of Engineering, University of Surabaya (UBAYA) in collaboration with The University of Adelaide, Australia and Sirindhorn International Institute of Technology (Thammasat University), Thailand.

InCITE 2019 has received more than 75 papers to be presented in this conference. All papers represent four following parallel clusters: Green Design and Innovation, Green Manufacturing and Green Processes, Power System and Green Energy Management, and The Role of IT in Innovation Enhancement. Each cluster supports the main theme of the conference, which is **Enhancing Engineering Innovation Towards A Greener Future.** The engineering innovation is the key to increase our awareness in maintaining the sustainable growth and development in the world.

The Organising Committee of InCITE 2019 would like to express our sincere gratitude for the tremendous supports and contributions from many parties. The supports from The Faculty of Engineering of UBAYA, keynote and plenary speakers, our International Scientific Committee, the Steering and Organising Committees are really acknowledged.

The last but not the least, thank you for your supports, enjoy the conference and we hope through this meeting all of you can extend your networks and collaborations.

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CONFERENCE ORGANIZING COMMITTEE:
FACULTY OF ENGINEERING, UNIVERSITAS SURABAYA
DEAN BUILDING TB 2, RAYA KALIRUNGKUT
SURABAYA, 60293, INDONESIA
PHONE: +62-31-2981150, FAX: +62-31-2981151
E-MAIL: incite@unit.ubaya.ac.id
WEBSITE: https://incite.ubaya.ac.id; http://teknik.ubaya.ac.id

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