JCBD
JOURNAL OF COMPUTERS AND DIGITAL BUSINESS
E-ISSN : 2830 - 3121
Vol. 3, No. 3, September, 2024, pp. 112-120

Comparison Classification Of Tomatoes Ripeness Based On RGB, HSV And CMYK Colors Based On Correlation Coefficient

Kiswara Agung Santoso [1*], Ahmad Kamsyakawuni [2], Siti Virna Rohmatul Izza[3]
[123] *Department of Mathematics, University of Jember, Jember, Indonesia*

* kiswara.fmipa@unej.ac.id

DOI : 10.56427/ jcbd.v3i3.410

ARTICLE INFO

Article History
Accepted : June 21, 2024
Reviewed : July 11, 2024
Approved : September 30, 2024

Keywords
CMYK,
RGB,
HSV,
Coefficient of correlation,
Color Space,
Classification

ABSTRACT

This article discusses the classification of tomato fruit maturity based on color space. Several studies have been conducted to measure maturity levels using RGB and HSV color spaces. In this article, researchers classify the ripeness of tomatoes using the CMYK color space, which researchers have never done before. Next, the classification results of the CMYK color space are compared with the RGB and HSV color spaces. The CMYK color space is a secondary color commonly seen by the human eye. CMYK colors are colors produced from a combination of RGB colors. Comparison of classification results based on CMYK, RGB, and HSV color spaces was carried out using the correlation coefficient and mean square error (MSE). The correlation coefficient is a method that is often used to measure the similarity between 2 images, where the closer to 0 the correlation value, the better.

1. Introduction

Tomatoes are a source of potassium and folate that can reduce cancer risk [1]. Tomatoes are characterized by physical changes in the skin of tomatoes from Raw to ripe tomatoes. This is due to the formation of carotenoids that cause changes in the color of tomato skin from green to red [2]. Determination of the maturity level of tomato fruit has been done manually so it takes a relatively longer time. Due to subjectivity, this can result in various tomato fruit products on the same tomato product.

Image processing is a branch of knowledge in Artificial Intelligence that uses images in digital form to solve several problems [3]. It can be applied in the analysis of the maturity level of tomatoes based on the characteristics of the discoloration of the skin which changes along with the maturity of the tomatoes. In this case, the pixel value of the image can be a feature that will determine the maturity level of tomatoes. The application of tomato skin similarity analysis can help to determine which tomatoes cannot be harvested until they are suitable for consumption. This study determines the level of maturity of the fruit guava by using fuzzy logic. Based on the category of guava fruit will be classified into 4 categories, namely unripe, half-ripe, ripe, and very ripe. The characteristics of the guava fruit are extracted based on RGB to form a fuzzy set and its rules fuzzy. Subsequent research was conducted by [5] on the classification of tomato ripeness with color space variations using a support vector machine. This study discusses the classification of tomatoes based on RGB. Red, Green, and Blue (RGB) is the color space in the image. Digital images are generally processed based on RGB colors because they are primary colors. Another study conducted by [6] discussed the classification of the ripeness of mangoes based on HSV images using the KNN method. The research was conducted by classifying the maturity level of mangoes with HSV images. Hue, Saturation, and intensity Value (HSV). It is a color space in an image. The HSV color space has the same colors that can be perceived by the human senses. [7] conducted a study entitled Old Determination Roasted Coffee Based on Roast Degree Variations Using the RGB Color Model in Digital Image Processing. The research was carried out to analyze RGB characteristics and then to analyze the relationship between image characteristics, roasting time, and degree variations. Analysis of the relationship between variables is to use the correlation coefficient.

In this study, the authors tried to apply a classification of color similarity based on the image of tomatoes. Several studies have been conducted using RGB feature extraction or HSV image transformation [8]. This can be a reference for the same application in the case of image transformation to Cyan, Magenta, Yellow, and Key (CMYK) images. CMYK images are the secondary colors that are more commonly seen by the human eye. CMYK color itself is a color space that is produced from a combination of primary colors or RGB. So it is expected to obtain identification results that are not much different. Identification will be strengthened by using a correlation coefficient. Coefficient. Correlation is often used in cases to measure the degree of closeness of the relationship between two variables. This can be applied in terms of detecting the similarity of an image by analyzing the level of similarity between images. Tomatoes Based on RGB, HSV, and CMYK Colors Using Correlation Coefficients.

1.1. RGB color in image

RGB image is a color image consisting of three elements, namely Red, Blue, Green or commonly known as Red, Green, Blue (RGB). The image can be obtained from the amount of light or light reflected by the object [9]. One example of the form of an RGB digital image is a color image. A color image has a color format, the color format in an RGB image pixel consists of three layers or three parts, namely Red, Green, and Blue. RGB images in the current cluster of technology have at least 16 million colors or the equivalent of 24-bit color, this can be seen for example in the recorded images from a smartphone or computer monitor. On a computer monitor, the smallest color range is 0 and the largest is 255. The 255 scale is based on 8 digit binary numbers used by computer monitors. RGB images are also based on triplets where each color has the brightness of all red, green, and blue color elements.

1.2. HSV color in image

The Hue, Saturation, Value (HSV) color system is a color system that is one of the methods used in selecting the color of an object in image processing or digital images. HSV color is closer than the RGB system in describing the sensation of color by the human eye [10]. HSV digital image defines color in terms of hue is the actual color. The actual colors in question are red, purple, and yellow which are also used to determine redness, blueness and others. Saturation is the purity of color which is also called chroma or color strength. Value is the brightness of the color with a value of 0-100%. 0% brightness of the color will be black, while the greater the percent value in the color, the more varied the color shown. The advantage of HSV is that there are colors that are the same as those captured by the human senses [11]. Hue, Saturation, Value (HSV) color space is a derivative of RGB color space [12]. The coordinates in RGB are assumed (0 or 1) are sequential red, green, blue in RGB color space, with max being the maximum value of RGB and min being the minimum value of RGB. The equations used to convert RGB into HSV form are in equations (1) to (3).

$$V = \max(R, G, B) \quad (1)$$

$$S = \begin{cases} 0 & , Pixel\ value = 0 \\ \frac{max - min}{max} & , other \end{cases} \tag{2}$$

$$H = \begin{cases} 0 & , S = 0 \\ 60° \times \left(\frac{G-B}{\max - \min}\ mod\ 6\right) & , max = R \\ 60° \times \left(\frac{B-R}{\max - \min} + 2\right) & , max = G \\ 60° \times \left(\frac{R-G}{\max - \min} + 4\right) & , max = B \end{cases} \tag{3}$$

1.3. CMYK color in image

The cyan, magenta, yellow, and key (CMYK) color space is a secondary or subtractive color that is usually used in print media. This color space is the result of a combination of 2 colors with a color ratio of 1: 1 from the primary color, RGB. The reason CMYK color space is the color that is more often used in print media is that CMYK color is a color that adjusts by reducing the intensity of the reflected light. Human vision sees light reflected by objects, therefore CMYK colors absorb and reflect light to produce certain colors. CMYK color is a complementary space to colors from RGB. CMYK colors have color elements Cyan, Magenta, Yellow and Key or commonly known as Black. Two color elements will be called complementary if mixed in the right ratio to produce white. Cyan, magenta, yellow pigments can be combined to absorb all light and produce black. The colors in CMYK when mixed with the right RGB color will produce white, for example cyan mixed in the right ratio with red will produce white, therefore cyan is the complement of red. By changing the RGB scale [0, 255] to [0, 1] the formula used to transform RGB colors to CMYK can be written as equations (4) to (8) [13].

$$C = 1{,}0 - R - uK_b \tag{4}$$

$$M = 1{,}0 - G - uK_b \tag{5}$$

$$Y = 1{,}0 - B - uK_b \tag{6}$$

$$K = bK_b \tag{7}$$

Within

$$K_b = \min(1{,}0 - R, 1{,}0 - G, 1{,}0 - B) \tag{8}$$

1.4. Coefficient of correlation

The coefficient of correlation is a value to express the strength or weakness of the relationship between two variables in a linear function [14]. Correlation is intended for cases of degree of two variables. The correlation coefficient is not a problem-solver in cases of causal relationships. The correlation coefficient can apply to the case of digital images. In digital images, the correlation coefficient is used as a matching metric to calculate the similarity degree or dissimilarity degree of two feature vectors [15]. The correlation coefficient interval can be written $-1 \leq r_{ij} \leq +1$. The higher the correlation value, the more similar the two feature vectors are [16]. Manual calculation of the correlation coefficient can be done with equation (9) [17].

$$r_{ij} = \frac{\sum_{k=1}^{n}(X_{ik}-\bar{X}_i)(X_{jk}-\bar{X}_j)}{\sqrt{\left(\sum_{k=1}^{n}(X_{ik}-\bar{X}_i)\right)^2\left(\sum_{k=1}^{n}(X_{jk}-\bar{X}_j)\right)^2}} \tag{9}$$

1.5. Mean Square Error (MSE) measurement

Mean Square Error (MSE) is a method used to find the average error in an image. When analyzing MSE, a comparison will be made between the test image and the reference image. The smaller the MSE value, it can be said that the image quality is almost the same or similar to the original image [18]. This can be interpreted that a small MSE value indicates that the two images are similar or identical. MSE calculation can be done with equation (10).

$$MSE = \frac{1}{NM}\sum_{x=1}^{N}\sum_{y=1}^{M}(p(x,y) - q(x,y))^2 \quad (10)$$

2. Research methodology

1. The following is the method used to complete this research:

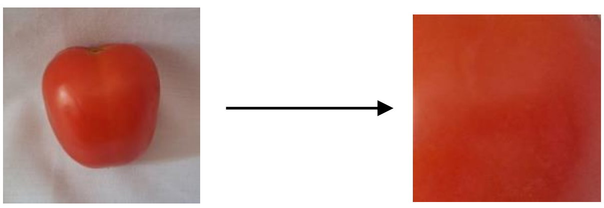
1. Input image data for raw, ripe, half-ripe, and rotten tomatoes, 15 images for each criteria
2. Crop each image to get the fruit skin needed for analysis.
3. Perform quantization to get the RGB value for each existing tomato image
4. Convert from RGB to HSV and CMYK on each image
5. Calculate the average RGB, HSV, and CMYK on tomatoes using the criteria of raw, semi-ripe, ripe, and rotten which will later be used as a reference
6. Carry out tests on 20 types of tomatoes whose RGB, HSV, and CMYK values have been calculated
7. Calculate the correlation coefficient between the testing image and the reference image, followed by calculating the error rate (MSE)

3. Results and Discussion (11 pt)

In this In this section, we theoretically establish a classification method for the sample tomato images. The image is tested by analyzing the similarity in the image of tomato fruit. The reference image is selected and categorized into 4 namely raw, half-ripe, ripe, and rotten then the pixel value will be calculated based on RGB, HSV, and CMYK then will be used as a reference value. Then the image of tomato fruit will be tested and analyzed for maturity according to RGB, HSV, and CMYK colors. The data in the test image will also be calculated as the pixel value and then the correlation coefficient will be calculated to determine the similarity between the test image and the references

Pre-processing

The first process is image cropping. The cropping process is first carried out to extract the part and remove the part of the image that is not needed. The selection area is the area that represents the tomato fruit. In this process, the image resolution is changed to 500x500 for each criterion so that it gets the same treatment and with a resolution that is not too large it can speed up the computing process.



(a) (b)

Figure 1: (a) The original image: (b) The image after cropping area of image.

The image that has gone through the cropping process will then be resized. Resizing is a process carried out with the aim of the image having the same pixel scale. The scale of the tomato fruit image is changed to a scale of 1000×1000 pixels. At this scale the image will produce a matrix with a format of 1000 rows and 1000 columns. The same image pixel scale will also affect the next image process.

3.2 Feature extraction

Feature extraction is done to obtain features or information that is in the image or image. The data used in this research is in the form of colored tomato fruit images. The image will then be analyzed for its components based on 3 components, namely RGB. RGB image at each pixel has three color components namely Red (R), Green (G). and Blue (B). Each component or color layer has a pixel value with intensity from 0 to 255. Tomatoes images that have gone through the pre-processing stage will be extracted from the Red, Green, and Blue pixel values. In data pre-processing, rescaling the matrix becomes a reference for the number of matrices that will be generated during the feature extraction process. Characteristic extraction performed on the image in addition to changing the image scale is also done changing the intensity scale from [0, 255] to [0, 1].

Image characteristics based on RGB that have been obtained will be changed or transformed into HSV form to determine the characteristics of the image based on its Hue, Saturation, Value elements. RGB to HSV image transformation can be obtained by applying equations (1) through (3). The next process is to look for image characteristics based on CMYK. The RGB image that has been obtained in addition to being transformed into HSV form will also be transformed into CMYK or Cyan, Magenta, Yellow and Key form. Transforming CMYK can use equations (4) through (8).

Table 1: Feature value of reference tomato based on RGB, HSV and CMYK color

Category	Feature			
RGB				
	R	**G**	**B**	
Raw	0,5676	0,5445	0,0756	
Half-Ripe	0,6913	0,3388	0,0288	
Ripe	0,6933	0,1859	0,0981	
Rotten	0,6896	0,2041	0,0869	
HSV				
	H	**S**	**V**	
Raw	56,9719	0,8729	0,5684	
Half-Ripe	27,9131	0,9557	0,6913	
Ripe	8,7185	0,8583	0,6933	
Rotten	11,6553	0,8761	0,6896	
CMYK				
	C	**M**	**Y**	**K**
Raw	0,2166	0,2396	0,7086	0,4316
Half-Ripe	0,1544	0,5068	0,8168	0,3087
Ripe	0,1533	0,6607	0,7485	0,3067
Rotten	0,1552	0,6407	0,7579	0,3104

The feature extraction performed can be used as information to analyzing the different images from each other. The reference image data that has gone through the feature extraction process will become a reference for classification in the test data. The characteristic values obtained on the reference image will be the reference for classification. Classification is done using the correlation coefficient. Based on the values or matrices that have been obtained, a correlation coefficient test will be conducted to determine the degree of similarity between the test image and the reference image. Table 4.1 to Table 4.3 is the average value of the characteristics extracted from tomato reference data based on RGB, HSV and CMYK.

3.3 Classification

The next stage is image classification. The image classification carried out is the classification of 20 test data based on 4 categories in the reference image, namely raw, half-ripe, ripe and rotten. The test data used is tomato fruit data that has been collected and then documented and pre-processed. The data after going through the feature extraction process will then be analyze for the correlation coefficient value. The correlation coefficient value will be used to identify whether the data belongs to the raw, half-ripe, ripe and rotten categories. The higher the correlation coefficient value, the more identical the two images between the test image and the reference image.

The calculation of the correlation coefficient is done using equation (9). Each layer in the RGB image will be compared and correlated with each layer in the reference image based on 4 categories. Suppose the R or Red layer in the test image will be calculated the correlation coefficient with the R layer in the tomato image in the raw, half-ripe, ripe and rotten categories. Each layer will be correlated with the same layer in each category on the reference tomato. The results of the correlation coefficient on each layer with the category will be averaged. The average will be the value to determine the classification of the test image. In addition to the calculation of the correlation coefficient, the MSE or error value is also calculated. Each test image data and reference image that is compared will be calculated and analyzed for error value. Table 2 until table 4 is a table of classification results based on correlation calculations and error values. The classification result is by considering the calculation results of the correlation size and also the size of the error value. The greater the correlation and the smaller the error value, the more similar the two images are.

Table 2: Correlation results based on RGB color

Data Test	Correlation				Result
	Raw	Half-Ripe	Ripe	Rotten	
Tomato 1	0,5431	0,6824	0,7611	0,3341	Ripe
Tomato 2	0,5656	0,5403	0,6645	0,3018	Ripe
Tomato 3	0,6356	0,6127	0,7962	0,3834	Ripe
Tomato 4	0,5491	0,6660	0,7803	0,2691	Ripe
Tomato 5	0,3757	0,4716	0,4230	0,2136	Ripe
⋮	⋮	⋮	⋮	⋮	⋮
Tomato 20	0,2309	0,1362	0,2213	0,1592	Ripe

Table 3: Correlation results based on HSV color

Data Test	Correlation				Result
	Raw	Half-Ripe	Ripe	Rotten	
Tomato 1	0,6453	0,7274	0,8075	0,2481	Ripe
Tomato 2	0,5320	0,4918	0,5904	0,2068	Ripe
Tomato 3	0,6879	0,6059	0,7893	0,2974	Ripe
Tomato 4	0,5829	0,6112	0,7256	0,1938	Ripe
Tomato 5	0,6627	0,6505	0,672	0,2170	Ripe
⋮	⋮	⋮	⋮	⋮	⋮
Tomato 20	0,2610	0,1605	0,2275	0,2634	Ripe

Table 4: Correlation results based on CMYK color

Data Test	Correlation				Result
	Raw	Half-Ripe	Ripe	Rotten	
Tomato 1	0,5415	0,7910	0,8361	0,2619	Ripe
Tomato 2	0,5508	0,6770	0,7297	0,2435	Ripe
Tomato 3	0,6487	0,6928	0,8052	0,3364	Ripe
Tomato 4	0,5401	0,7686	0,8380	0,2194	Ripe
Tomato 5	0,5645	0,7808	0,7651	0,1745	Ripe
⋮	⋮	⋮	⋮	⋮	⋮
Tomato 20	0,3152	0,1505	0,2908	0,1594	Ripe

Based on the calculations that have been carried out, a comparison of the results on the classification between RGB, HSV and CMYK is obtained. The results obtained show that there are some differences in the results of calculation and classification. This is due to the color transformation performed. The classification results between RGB, HSV and CMYK performed on 20 test data are in Table 5.

Table 5: Comparison of classification result

Category	Total Data		
	RGB	**HSV**	**CMYK**
Raw	5	4	5
Half-Ripe	5	6	5
Ripe	9	7	9
Rotten	1	2	1

The classification results based on Table 5 show a comparison of the classification results, in the RGB color space there are 5 tomato test data in the raw category, 5 tomato test data in the half-ripe category, 9 tomato test data in the raw category and 1 rotten category. Raw category and 1 test data including the rotten category. While the classification results based on HSV are for the raw category totaling 4 tomatoes, the half-ripe category totaling 6 tomatoes, the ripe category totaling 7 tomatoes and the rotten category totaling 2 tomatoes. Classification results based on CMYK show that of the 20 test data 5 tomatoes belong to the raw category, 5 tomato test data belong to the half-ripe category, 9 test data belong to the ripe category and 1 test data belongs to the rotten category. Classification based on RGB and CMYK has similarities in the classification results of each category. In addition to the comparison of classification results, there is also a comparison of the resulting correlation range in Table 6.

Table 6: Comparison of coefficint of correlation

Color	Correlation Range
RGB	$0{,}22 - 0{,}86$
HSV	$0{,}20 - 0{,}84$
CMYK	$0{,}26 - 0{,}87$

The correlation range is obtained from the results of the minimum correlation value to the maximum correlation. Some of the correlation magnitudes produced according to the interval have low to very strong correlations.

Based on Table 6 in the correlation range, the correlation results based on the Red, Green and Blue elements are in the range of 0,22 to 0,86. The largest correlation based on the raw category in the test data with the reference data is 0,78. The largest correlation in the half-ripe category is 0,86. In the ripe category, the largest correlation is 0,79. Classification in the rotten category has the largest correlation of 0,22. The classification carried out next is classification based on Hue, Saturation and Value (HSV) elements. The correlation results based on Hue, Saturation and Value elements are in the range of 0,20 to 0,84. Classification based on HSV elements is in the raw category with the largest correlation of 0,66. Next is the half-ripe classification. The largest correlation obtained in the half-ripe category is 0,84. In the ripe category classification the largest correlation is 0,80 and the classification in the rotten category the largest correlation is 0,20. Next is the classification based on CMYK elements. CMYK elements consist of Cyan, Magenta, Yellow and Key, each of which is obtained from a mixture of RGB element colors. The correlation value obtained in the classification based on CMYK is in the range of 0,26 to 0,87. Classification results based on CMYK elements for the raw category have the largest correlation value of 0,69. Classification in the half-ripe category based on CMYK has the largest correlation coefficient of 0,87. Next is the classification in the ripe category. The classification results with the ripe category produce the largest correlation of 0,83 and the rotten classification results have the largest correlation of 0,26.

The results of the calculation of the correlation coefficient and MSE affect the classification results. From the calculation results there are several comparisons of the resulting correlation. The highest correlation based on RGB is worth 0,86 with an average MSE value of 0,0061. Next is the largest correlation in the HSV category with a value of 0,84 with an average MSE value of 0,0066. For correlations based on CMYK the largest correlation is 0,87 with an average MSE value of 0,0047. So of the three color spaces the most suitable is the

CMYK color space. In addition, the classification results based on CMYK have a correlation coefficient to produce the highest similarity with a coefficient value of 0,87 with an average MSE value of 0,0047 so that the selected tomato classification results are the classification results based on CMYK.

4. Conclusion

Based on the research that has been done, it can be concluded that the application of the correlation coefficient method for fruit ripeness classification is by reading the matrix obtained from the pixel value. In addition to the correlation coefficient, the MSE calculation is also carried out to determine the error value or error during classification. The greater the correlation value and the smaller the MSE value, the more similar the two images will be. From the classification comparison results for the three color spaces (RGB, HSV and CMYK), it shows a difference in the amount of correlation. The highest correlation coefficient in RGB color space is 0,86. In HSV space it is 0,84 and in CMYK space it is 0,87. Based on the correlation coefficient value, it is found that the best space obtained is the classification based on CMYK. This is because it produces the highest similarity of the test image with the reference, namely the value with a coefficient of 0,87.

.

References

[1] R. Novaldy, R. N. Iyos, The Effect of Tomato (Solanum lycopersicum) in Prostate Carcinoma Risk Reduction. *Majority Journal: Medical Journal Of Lampung University*, 2022, p. 150-154

[2] S. F. Sholeha, D. W. Soedibyo, Sutarsi. Assessment of Physical and Chemical Properties of Tomato (Lycopersium escuslentum Mill) Using Image Processing. *Berkala Ilmiah Pertanian*, 2018, p.1-6

[3] M. T. Suwindra, Ernawati, Elansari, A. Bird Species Similarity Analysis Using Siamese Neural Network Analysis Of Bird Species Similarity Using Siamese Neural Network. *Rekursif Journal*, 2021, 9(2), p. 193-205.

[4] Munir,. *Digital Image Processing with an Algorithmic Approach*. 2014, Bandung Informatika.

[5] J. Jumadi, Yupianti, D. Sartika, Digital Image Processing for Object Identification Using Hierarchical Agglomerative Clustering Method. *JST Journal*, 2021. 10(2), 148-156.

[6] K.A. Santoso, Fatmawati., Suprajitno. On Max-Plus Algebra and Its Application on Image Steganography. *Scientific World Journal*, 2018, 1087-1096.

[7] Khotimah, H. N. Nafi'iyah, Masruroh. Classification of Mango Fruit Maturity Based on HSV Image with KNN. *ELTI Journal*, 2019, 1(2), p. 1-14.

[8] B. Marhaenanto, D. W. Soedibyo, M. Farid, Determination of Coffee Roasting Time Based on Variation of Roasting Degree Using RGB Color Model in Digital Image Processing. *Agroteknologi Journal*, 2019, 9(2), p. 102-111.

[9] N. K. Ningrum, T. E. Sasmita. Color Extraction Based on RGB to Determine the Maturity Level of Tobacco Leaves. *Proceeding of SNATIF*, 2018, 44(5), p. 373-378.

[10] F. Liantoni, F. N. Annisa, Fuzzy K-Nearest Neighbor for Chili Maturity Classification Based on HSV Image Features. *Journal of JIPI*, 2018. 3(2), p. 101-108.

[11] Fauzi, J. F., Tolle, H., and Dewi., R. K. Implementation of RGB To HSV Method on Android-Based Paper Currency Recognition Application for the Visually Impaired. *Journal of J-PTIIK*, 2018, 2(6), p. 2319-2325.

[12] K. A. Santoso, R. A. Sukmawati, A. Pradjaningsih, Image security development using 3D playfair cipher combination and bit shift. *AIP Conference Proceeding*, (2022). 020013.

[13] R. Rahmadewi, G. L. Sari, and H. Firmansyah, Citrus Fruit Maturity Detection with Fruit Peel Image Features Using HSV Color Space Transformation. *JTEV Journal*, 2019, 5(11), p. 166-171.

[14] Pratt, and K. William*Digital Image Processing*. New York: John Wiley & Sons, Inc.

[15] Paiman. (2019). *Correlation And Regression Analysis Techniques In Agricultural Sciences*. 2001, Yogyakarta: UPY Press.

[16] M. Zen, Comparison of Fractal Dimension Method and Backpropagation Artificial Neural Network in Fingerprint Identification System on Digital Image. *JITEKH Journal*, 2019, 7(2), p. 42-50.

[17] M. I. Mulyadi, R. R. Isnanto, A. Hidayatno. Fractal Dimension Based Feature Extraction. *TRANSIENT Journal*, 2013, 2(3), 751-756

[18] K. A. Santoso, M. L. Najah, Moh. Hasan, Image Authentication Based on Magic Square. *Advances in Computer Science Research*. 2022, https://doi.org/10.2991/acsr.k.220202.043

[19] N. A. Juwitarty, K. D. Purnomo, K. A. Santoso, Detection Of Plant Leaf Images Using The Box Counting Method. *Majalah Ilmiah Matematika Dan Statistika*, 2020, *20*(1), p. 35-41

[20] Mundir. *Educational Statistics Introduction to Data Analysis for Thesis and Thesis Writing.* Jember: STAIN Jember Press. (2012).

[21] I. W. Kusuma, R. L. Ellyana, Application of Compressed Image to Image Segmentation Using K-Means Alhorithm. *JUTEI Journal*, 2018, 2(1), p. 65-74.

[22] M. L. Firdaus, Okumura, R. M. Nursaadah, E. Handayani, D. Mayub, A. Rahmidar, L. Permana, M. D., Luthfiah, A. Wyantuti, SColorimetric Sensing of Ascorbic Acid Using Cu-Phen MOFs and Subsequent Digital Image Analysis with Smartphone. *Science and Technology Indonesia*, ., 2023, *8*(4), p. 660–665.

[23] D. Kurniasari, W. Warsono, M. Usman, F. R. Lumbanraja, LSTM-CNN Hybrid Model Performance Improvement with BioWordVec for Biomedical Report Big Data Classification. *Science and Technology Indonesia*, 2024, *9*(2), p. 273–283.

[24] K. A. Santoso, A. Kamsyakawuni, M. Seggaf, Medical Image Encryption Using Dna Encoding And Modified Circular Shift. *BAREKENG: Jurnal Ilmu Matematika Dan Terapan*, 2022, *16*(1), p. 235–242.

[25] S. Nabila, A. Srihardyastutie, S. Prasetyawan, A. Aulanni'am, R. Retnowati, The Addition of Red Dragon Fruit and Lemon Peels for the Improvement of Fermented Beverage Products. *Science and Technology Indonesia*, 2023. *8*(1), p.100–107.