Classification of Facial Expression Using Principal Component Analysis (PCA) Method and Support Vector Machine (SVM)

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Abstract— **Classification is a process to assert an object into one of defined categories. This study examines the classification of recognition of student's facial expression during digital learning –indifferent and serious expression. The dataset used was from a vocational school -SMK Muhammadiyah 2 Bantul. This study used the combination of algorithm: Principal Component Analysis (PCA) and Support Vector Machine (SVM) to increase the accuracy. This study aims at comparing the performance of combination of two algorithm: (PCA to SVM) and (PCA to k-NN). The result states that the combination of PCA-SVM algorithm is higher than the combination of PCA-k-NN algorithm with the average accuracy of 96% and 89%.**

Keywords- Classification; PCA; SVM

I. INTRODUCTION

Covid-19 pandemic makes Indonesian goverment take new policies. One of them is asking the citizen to do physical distancing such as away from any crowd, gatherings, and avoiding any meetings, including learning activities at school [1]. As the result, schools in Indonesia are temporaryly shut in order to end Covid-19 spreading [2]. However, although schools are closed, learning activities cannot be left. The minister of education and culture, Nadiem Anwar Makarim, published Circular Letter Number 3 in 2020 to educational institutions and Number 36962/MPK.A/HK/2020 about Educational Mechanism during Emergency Period of Corona Virus Disease (Covid-19). Thus, learning activities are held digitally in order to prevent COVID-19 spreading [3].

Digital learning activity is a kind of learning which is held by distance using internet and any other supporting facilities such as celular phone and computer [4]. It needs the teacher to take attention on students' presence, activeness, and expression during learning activity through application such as Zoom, Google Meet, and Google Classroom. In fact, teachers are confused to determine students' facial expression during the digital learning.

Facial expression is one of the mechanisms –known as nonverbal commuication- to express emotional feeling, either negative or positive feeling [5]. One of the techniques in recognizing facial expression which can be used to recognize faces is Feature Extraction. This technique is the core in diagnosis, classification, grouping, recognition, and detection [6]. One of the approches used to recognize facial expression is Principal Component Analysis (PCA) approach. PCA shows good result when it is applied on interrelated data.

In this study, PCA algorithm is used to recognize the pattern in collecting data and finding similarities and differences among each attribute [7]. It is also used to categorize student's facial expression, either indifferent or serious expression. The resulted extraction will be used to classify. Classification is a technique used to predict property or class in each of the instace data. This technique is done by manipulating data which is collected and classified until it produces several determining rules [8] [9]. This study aims at comparing the combination of application of PCA-SVM to PCA-k-NN to show the optimal result, that is the level of accuracy of classification of resulted facial expression. The result of this test proves that the algorithm combination of PCA-SVM shows the accuracy value at 96%. This result is better than the algorithm combination of PCA-k-NN in which it has the average accuracy at 89%.

II. RELATED WORKS

The previous study was related to classification system of face recognition of men and women using SVM which had an average accuracy value at 88.13% whereas k-NN had 84.4% [10]. The study of automatic recognition of facial expression could recognize eight basic facial expressions: normal, happy, angry, surprised, sad and , frightened. The method used were three different classifications: SVM, k-NN, and Multilayer Perception Neural Network (MLPNN). They were used to classify facial expression. The result, then, was compared. The result of experiment showed that the used method gave a recognition level at 93, 53% when it used SVM classifier, at 82,97% when it used MLPNN classifier, and at 79,97% when it used k-NN classifier. It could be concluded that SVM showed

a higher result than two other classifiers [11]. It also found that SVM was an algorithm which worked by a linier classifier which could be used for classification process. SVM was also used to recognize facial expression using Geometric and Appearence Feature method. Face recognition was done by comparing a neutral to expressive facial expression. This experiment was done using Cohn-Kanade database in which it showed an accuracy at 95% [12].

The recognition of facial expression was an interesting research topic. It let a more neutral interaction between human and computer. In this paper, a system of facial expression recognition was served by Local Binary Pattern (LBP) method as the method of characteristic extraction. LBP had a quick count mechanism because of its simple algorithm. On the other hand, it showed facial characteristics efficiently. The experiment was undertaken using JAFFE dataset. The classification was done using k-NN and SVM method with one-against-one schema. The experiment showed that LBP method could give a discriminative characterictic of facial expression. The experiment showed a highest accuracy at 84% on person-dependent test schema by LBP operator configuration (p=8, r=8) and segmentation at 16 areas [13].

A study of face classification was a technique which could be used to differentiate the characteristic of someone's facial pattern. The system of face classification was an application which made a machine could recognize somebody's expression according to facial image which was trained and saved into the database of that machine. The face classification could be done through many ways. One of them was SVM method. This experiment was done using sampling which was taken at variation of position in any oblique of the subject: -90%, -70%, -45°, -25°, -5°) and (+90°, +70°, +45°, +25°, +5°) with the size of the image 640x480. The system of face classification in this study was created using SVM method and programming language, Matlab. This study showed the level of true detection at 90% and false detection at 10% from all of the 200 subjects used.

III. RESEARCH METHODS

The steps of classification process of this study can be seen in Figure 1.

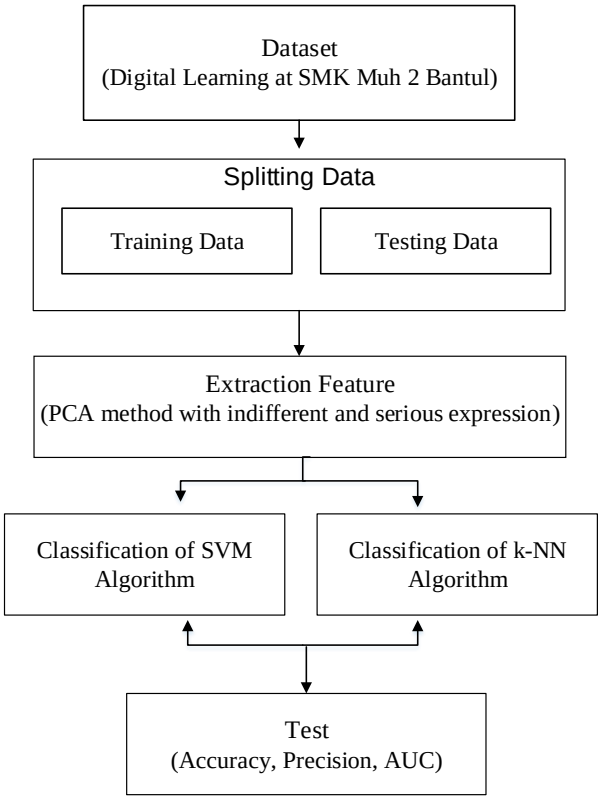

Figure 1. Schema of Classification of Student's Facial Expression

A. Dataset

The data used in this study are in the form of digital images. The digital images are collected from digital learning at SMK Muhammadiyah 2 Bantul. It uses the sample of students' facial expression from Zoom application. The sample which is categorized into indifferent and serious expression is already labelled by a pscycologist, Ermanto Atmoko, S. Psi., M. Si. The dataset contain 200 images which have 100x100 pixel in measurement and consist of 100 indifferent expressions and 100 serious expressions. The examples are as follows:

Figure 2. Dataset Example of Indifferent Facial Expression

Figure 3. Dataset Example of Serious Facial Expression

B. Splitting Data

Splitting data is a validation technique which randomly splits the data into two parts -training data and testing data. The training data will be tested based on split ratio using split validation. Then, the rest of split ratio of training data will be pretended as testing data. Training data is data which will be used in the learning process whereas testing data is data which is not used in learning process yet. It will function as testing data of truth or accuracy of learning result [15].

The test is done by dividing the data into training data and testing data. The tests are done 5 times with the proportion of training data and testing data: 90%:10%; 80%:20%; 70%:30%; 60%;40%; and 50%:50%.

C. Extraction of Facial Images

Feature Extraction uses Google Colabs and PCA algorithm. The extraction of student's facial expression uses PCA method. The procedure of PCA aims at simplifying the observed variable by reducing its dimension. It is done by omitting the correlation among independent variables through transformation of the source of independent variable to the new independent variable. This new variable is not correlated at all without omitting the important information inside or so called as Principal Component. By this reduction, the computation duration can be shortened and the complexity of needless facial image can be omitted. PCA uses vectors -called eigen vector- and values -called eigen value- to reach the most significant feature in the dataset [16]. The target of PCA is to catch the total variation on the character collection which is trained and to run the variety by few variables. An observation which is explained by few variables will be easier to be coped. It does not only reduce the complexity and computation duration but also manages the scale of every variable based on the position and relative interest in explaining the observation. In this study, application of PCA used is Sample Covariance Matrix:

- The first thing to do is standardising the data. For each sample, it needs to reduce the average of complete data collection. Then, it needs to be divided with the variant until it has the unity of variant. This last process is not fully needed but it is useful to let the CPU less work.

$$Z=\frac{X-\mu}{\sigma^2} \quad (1)$$

- Then it needs to count Covariance Matrix, remember the data

$$(X_1, X_2, X_3, \dots, X_n) \quad (2)$$

with total sample n, Covariance Matrix is acquired by:

$$\Sigma = \frac{1}{n}\sum_{i=1}^{n}(X_1 - \bar{X})(X - \bar{X})^T \quad (3)$$

In which

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad (4)$$

or only by multiplying matrix of standart Z with its transposition.

$$COV(x) = ZZ^T \quad (5)$$

- Principal Components will become eigen vector from Covariance Matrix which is in order according to the level of its importance based on each eigen value.
Eigen value is bigger → Eigen vector is more important.
Counting eigen value and eigen vector:

$$Cv_i = \lambda v_i \quad (6)$$

Eigen Value $(\lambda) = Det\,(C - \lambda I)$ (7)

Eigen Vector $(v_i) = (C - \lambda I)\, v_i$ (8)

D. Algorithm of Students' Facial Classification

- SVM

SVM is a method which works by defining the border between two classes with maximum distance from the nearest data. This maximum distance is obtained by finding the best hyperplane (separating line) in the input space acquired by measuring the hyperplane margin. Margin is a distance between hyperplane and the nearest vector from each class [17].

SVM is a classification method first introduced by Vapnik in 1998. This method works by defining the border between two classes with maximum distance from the nearest data. To acquire the maximum border inter-class, it needs the best hyperplane obtained in the input space by measuring hyperplane and finding the maximum vector. Margin is a distance between hyperplane and the nearest vector of each class. This nearest vector is called Support Vector Machine (SVM). SVM is able to classify linierly separable data and non linierly separable data. Hyperline of SVM can be seen at Figure 4 below: [14].

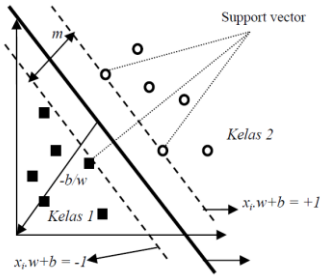

Figure 4. Hyperline of SVM

- k-NN

k-Nearest Neighbors (k-NN) is clasiffication of algorithm which works based on the nearest k instances through the given query instances. It chooses among k of the nearest neighbors to obtain the output label of the given query instances k-NN and saves all of the instances in the same spot in which n is the feature of instances which is previously defined. Matrix distance is used to measure the distance among instances. It can use Euclidean distance and Manhattan distance in the computation distance. x and y are 2 instances defined as <f1, f2...,fn >, for instace. Thus, by using Euclidean and Manhattan computation, the distance is defined as d1(x,y) and d2(x,y), so that the equation can be formulated as follows:

a. Euclidean

$$d1(x,y) = \sqrt{\sum_{i=1}^{n} | f_i(x) - f_i(y) |^2} \quad (15)$$

b. Manhattan

$$d2(x,y) = \sum_{i=1}^{n} | f_i(x) - f_i(y) | \quad (16)$$

The most influencing thing in the k-NN algorithm is the k value. The best k value of k-NN algorithm is depended on the data used. By using optimization, the parameter can determine the exact k value. In this study, k value is adjusted on 3. In the training step, k-NN algorithm only saves the feature vectors and classification of training data [18].

E. Evaluation Model

The tests on classification of students' face during digital learning are accuracy, precision, and AUC.

Accuracy is the closeness level between prediction value and actual value. It can be formulated by the following equation [19]:

$$\text{Accuracy} = \frac{TP + TN}{TP+TN+FP+FN} * 100 \quad (16)$$

Precision is the exactness between the information asked by user and the answer delivered by system. It can be formulated by this equation [19] :

$$\text{Precision} = \frac{TP}{TP+FP} * 100 \quad (17)$$

Area Under the Curve (AUC) is area under the curve of Receiver Operating Characteristic (ROC) in which the curve describes the probability through the sensitivity of variable and the specificity with limited value from 0 until 1.

IV. FINDINGS AND DISCUSSION

At this step, the first thing to do is preprocessing the data image by applying PCA method to extract the facial expression, either indifferent or serious expression. PCA method is used to simplify the variable by reducing its dimension. To find how the emerging data is lower, it needs to reduce the dimension of data collection into 2 or 3 dimension until it can be plotted and visualized. It is done using PCA method because it is suitable to insert a high dimension data. After Model of PCA Extraction is already served, the classification model of SVM and k-NN are tested. The result will prove the best performance of both of the algorithms. The steps of this experiment are stated as follows:

- Collecting Data

At this step, the researcher collected the data of students' facial image who learns digitally at SMK Muhammadiyah 2 Bantul.

```
#import zipfile
#with zipfile.ZipFile("/gdrive/My Drive/archive.zip","r") as zip_ref:
#    zip_ref.extractall("/gdrive/My Drive/data_wajah")
```

Figure 5. Collecting Data of Student's Facial Expression

- Splitting Data

At this step, the data used were devided into training data and testing data. There were 5 times of data testing like in the following Figure 6:

```
#Scale Data Images
scaler = StandardScaler()
X_train = scaler.fit_transform([i.flatten() for i in X_t])
X_test = scaler.fit_transform([i.flatten() for i in X_test])
X = scaler.fit_transform([i.flatten() for i in X])

There are  90   TRAINING  images of  SERIUS
There are  90   TRAINING  images of  ACUH
There are  10   TEST  images of  SERIUS
There are  10   TEST  images of  ACUH

There are  80   TRAINING  images of  SERIUS
There are  80   TRAINING  images of  ACUH
There are  20   TEST  images of  SERIUS
There are  20   TEST  images of  ACUH
There are  70   TRAINING  images of  SERIUS
There are  70   TRAINING  images of  ACUH
There are  30   TEST  images of  SERIUS
There are  30   TEST  images of  ACUH

There are  60   TRAINING  images of  SERIUS
There are  60   TRAINING  images of  ACUH
There are  40   TEST  images of  SERIUS
There are  40   TEST  images of  ACUH
There are  50   TRAINING  images of  SERIUS
There are  50   TRAINING  images of  ACUH
There are  50   TEST  images of  SERIUS
There are  50   TEST  images of  ACUH
```

Figure 6. Splitting Data

- Facture Extraction

. Facture Extraction combined with PCA is used to simplify the observed variable by reducing its dimension. To find how the data emerge in the lower dimension, it needs to reduce the dimension of data collection into 2 or 3 dimension until it can be plotted and vizualized. The illustration is in Figure 7 and 8 as follows:

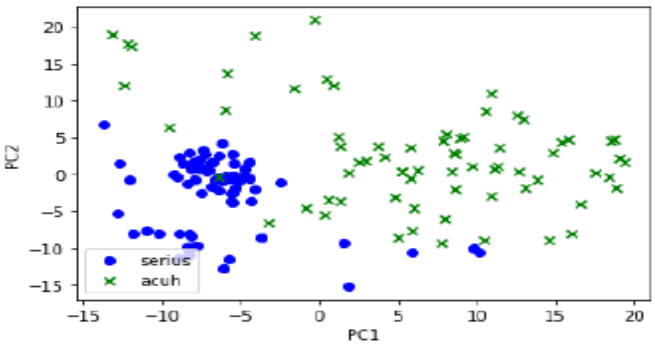

Figure 7. Visualisation of 2D PCA

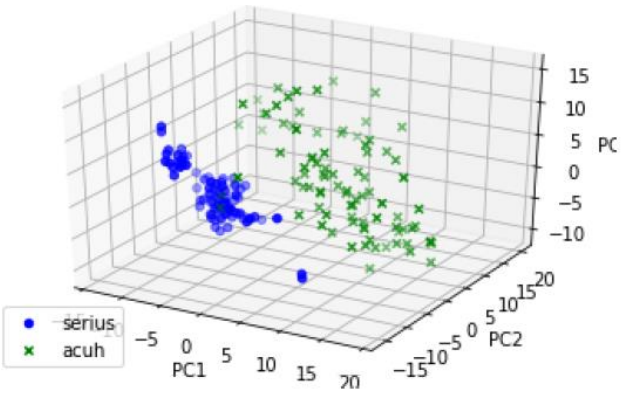

Figure 8. Visualisation of 3D PCA

The following figure is the result of PCA tabulation done with value of X2, X10, and X50. The cropping technique of input data into the valid range is shown by data RGB ([0. 1] as in the following Figure 9:

```
image_id = 2
image = X_t[image_id]

#Compute PCA
X_2 = computePCA(2, X_train,image_id)
X_10 = computePCA(10, X_train,image_id)
X_50 = computePCA(50, X_train,image_id)

#Reshape in order to plot images
X2 = np.reshape(X_2, (dim,dim,3)).astype(int)
X10 = np.reshape(X_10, (dim,dim,3)).astype(int)
X50 = np.reshape(X_50, (dim,dim,3)).astype(int)

#Plot
showPCA(image, X2, X10, X50)
```

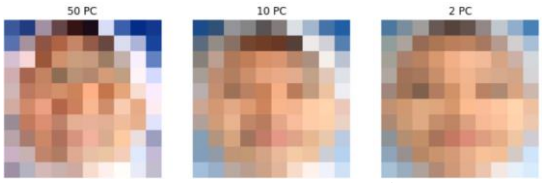

Figure 9. Example of PCA result

- Classification of SVM

Based on the result of SVM test using Google Colabs, it results accuracy, precision, and AUC like in the following Figure 9 and 10:

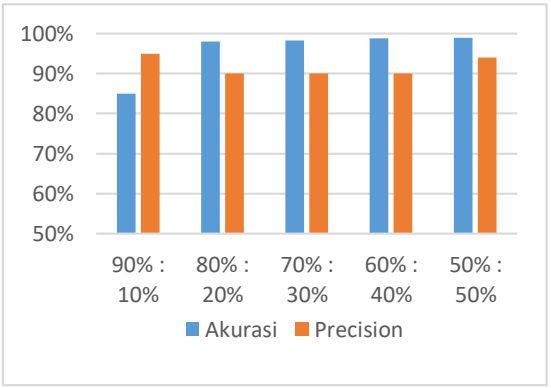

Figure 9. Result of Accuracy, Precision

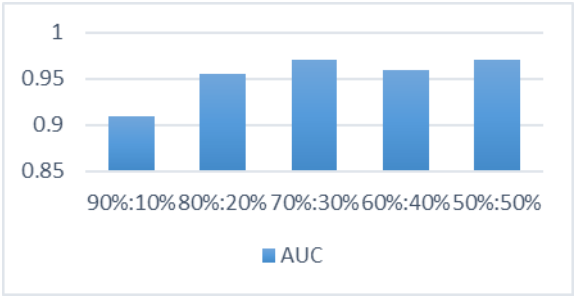

Figure 10. Result of AUC

Figure 9 and 10 show the result of data division, that is 90% of training data and 10% of testing data, which has

85% of accuracy, 95% of precision, and 0.91 of AUC. Then, the result of data division, that is 80% of training data and 20% of testing data, has 97,5%, of accuracy, 90% of precision, and 0,95% of AUC. Next, the result of data division, that is 70% of training data and 30% of testing data, which has accuracy of 98,33%, 90% of precision, and 0,96% of AUC. The last is the data division, that is 50% of training data and 50 % of testing data which has 90% of accuracy, 94% of precision, and 0.97 of AUC.

All of these testing results using SVM algorithm can be seen at TABLE 1.

TABLE 1. RESULT OF SVM CLASSIFICATION TEST

NO	TRAINING : TESTING	ACCURACY	PRECISION	AUC
1	90%:10%	85%	95%	0.91
2	80%:20%	97.5%	90%	0.95
3	70%:30%	98.30%	90%	0.97
4	60%:40%	98.75%	90%	0.96
5	50%:50%	99%	94%	0.97
Average		96%	92%	0.952

From TABLE 1, it can be seen that the average accuracy is 96%, the precision is 92%, and AUC is 0,952.

- k-NN Claasification

Based on the result of k-NN experiment using Google Colabs, the result of obtained accuracy, precision, and AUC are illustrated by Figure 11 and 12 as follows:

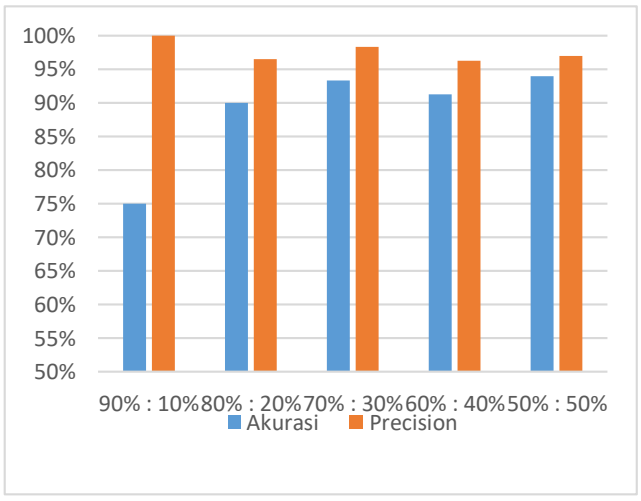

Figure 11. Result of Accuracy, Precision

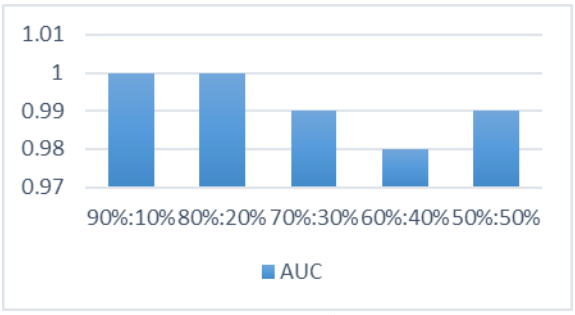

Figure 12. Result of AUC

Figure 11 and 12 show the result of data division, that is 90% of training data and 10% of testing data, has 75% of accuracy, 100% of precision, and 1 of AUC. Then, the result of data division, that is 80% of data training and 20% of testing data, has 90% of accuracy, 97.5% of precision, and 0.99 of AUC. Next, the result of data division, that is 70% of training data and 30% testing data, has 93.3% of accuracy, 98.3% of precision, and 0.99 of AUC. The result of data division, that is 60% of training data and 40% testing data, has 91.25% of accuracy, 96.25% of precision, and 0.98 of AUC. The last, the result of data division, that is 50% of training data and 50% testing data, has 94% of accuracy, 97% of precision, and 0.99 of AUC.

All of these testing results using SVM algorithm can be seen at TABLE 2.

TABLE 2. RESULT OF k-NN CLASSIFICATION TEST

NO	TRAINING : TESTING	ACCURACY	PRECISION	AUC
1	90%:10%	75%	100%	1
2	80%:20%	90%	97.5%	0.99
3	70%:30%	93.30%	98%	0.99
4	60%:40%	91.25%	96%	0.98
5	50%:50%	94%	97%	0.99
Avarege		89%	98%	0.99

From TABLE 2, it can be seen that the average accuracy is 89%, the precision is 98%, and AUC is 0,99.

From the test done using SVM algorithm and k-NN, the average result can be seen in the following TABLE 3:

TABLE 3. AVERAGE RESULT OF CLASSIFICATION TEST

EXPERIMENT	SVM	k-NN	EXCELLENCE
ACCURACY	96%	89%	SVM
PRECISION	92%	98%	k-NN
AUC	0.95	0.99	k-NN

It can be seen from TABLE 3 that SVM algorithm is more excellent at accuracy while k-NN algorithm is more excellent at precision and AUC.

V. CONCLUSION

Based on the test done, this study shows that:

1 The accuracy of SVM is higher than k-NN with comparisson 94% of SVM and 88% of k-NN.

2. The result for precision is that k-NN is higher than SVM with comparisson 98% of k-NN and 92% of SVM.

3. AUC shows that k-NN is higher than SVM with comparisson 0,99 of k-NN and 0,95 of SVM.

- Suggestion

The study of classification of students' face recognition using PCA method and SVM during digital learning has an important point to be noted for better future research, that is the image data. In collecting the image data, it needs to concern about the angle and sufficient lightness in order to get a more optimal accuracy result.

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