Performance of Contrast Adjustment in Face Recognition with Training Images under Lighting Variations

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***Abstract* — This study investigates the contrast adjustment technique for facial recognition in training images under different lighting conditions. In many previous studies, contrast adjustment techniques are often used in the pre-processing stage of face recognition to reduce the effect of lighting on the image, so that performance of face recognition can be optimal. Lighting is one of the factors that greatly affects the facial recognition system, so research in this case continues to be carried out to get better problem-solving concept. In this study, the contrast adjustment technique uses the histogram equalization method which is also widely used in many other studies. This study was intended to test the reliability of this technique in facial recognition with training images in various lighting conditions. Experiments were carried out empirically to determine whether the technique showed good performance in all lighting conditions of the training image or not. The face recognition process uses the Robust Regression method. In a number of previous studies, this method has shown a very good performance for recognizing faces that are affected by lighting factors. One of the facial image datasets, namely the AR Face Database, was used for testing in this study. The images used are related to the lighting factor. The images are grouped into 4 categories, including low, medium, high, and very high (extreme) lighting conditions. Experimental scenarios were carried out by comparing the results of face recognition with using histogram equalization technique at the preprocessing stage and face recognition without using contrast adjustment techniques in every lighting condition. Based on the testing process that has been carried out, under low, medium, and high lighting conditions, the performance of contrast adjustment using histogram equalization technique in facial recognition pre-processing is better than the approach without contrast adjustment. While in extreme lighting condition, the use of histogram equalization technique in preprocessing (average accuracy of 93.17%) results in lower facial recognition performance than the approach without using histogram equalization (average accuracy of 94.67%).**

Keywords — Face Recognition, Lighting Conditions, Contrast Adjustment, and Histogram Equalization.

I. INTRODUCTION

People's mobility is increasingly dynamic nowadays, moving from one place to another easily and quickly, along with the development of various transportation technologies. Access to a facility can be done by everyone easily too. This turned out to be a risk to the level of security. Biometric technology is considered as one of the right solutions to limit access to facilities, so that security can be increased. These restrictions are usually carried out to ensure that only authorized persons can access the facilities according to their level of importance and urgency. By using biometric technology, people's identities can be recognized and then grant access rights to them [1].

One of the most widely used biometric technologies today is facial recognition systems. This system allows the recognition of a person's identity because each person's face is unique, which is different from one another. In general, this approach is done by taking pictures of a person's face area using a camera and then matching the person's facial features with the image features in the database [2]. This very easy image data retrieval process makes facial recognition a popular biometric technology today. However, this technology is still difficult to achieve perfect results. Many problems related to this technology are still being researched until now. The problems that arise are caused by many factors that affect the reliability of the approach. Among these factors include expression, physical changes, age factor, attributes that cover the face, gender, position, illumination, noise, etc.

The scope of this research relates to lighting factors that significantly affect facial recognition performance. The face of the same person with the same position and expression but receiving several different lighting conditions can cause different identity recognition [3]. This is because lighting can cover or distort some areas of the face, making face recognition difficult. In other research, it has been shown that lighting variations are the main problem that affects the reliability of face recognition [4]. Other research also shows that illumination variations have a greater influence than other factors such as position and expression [5]. Various studies continue to be carried out by researchers to solve facial recognition problems caused by lighting conditions, especially in unrestricted illumination variations [6]. In this lighting condition, face recognition is very difficult. Contrast adjustment technique is widely used by researchers to

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normalize the knowledge of the image so that the image becomes neutral and easy to recognize. The process carried out in the pre-processing of face recognition is indeed able to produce a fairly good facial recognition performance, but in other research problems have been found that make facial recognition not optimal [7].

Various facial recognition approaches are used to solve the lighting problem. Robust Regression method is one method that shows high accuracy to solve the problem [8]. In the pre-processing stage of this method, the normalization of image illumination is performed using one of the contrast adjustment techniques, namely histogram equalization [9]. In general, the resulting facial recognition accuracy is quite high. However, it is not known in more detail whether the use of this histogram equalization technique really contributes to this performance and whether in all lighting conditions of the image. In this study, testing was carried out on each image lighting condition using representative training data. Theoretically, histogram equalization has the ability to normalize all images with variations in lighting conditions so that they have close contrast values, so that facial recognition accuracy is higher. But this conclusion needs to be investigated further to find out its effectiveness in every condition of facial illumination, as was done in this research.

II. Methodology

The approach to recognize faces in this research uses the Robust Regression method. The contrast adjustment process is applied at the pre-processing stage to neutralize the lighting conditions of the image. The contrast adjustment approach uses histogram equalization technique. The implementation of contrast adjustment in this research will be compared with the implementation of the robust regression method without using contrast adjustment in the pre-processing stage. Through empirical testing, it will be known the difference in the results of the two approaches. The facial images used in the experimental process in this study are the AR Face Database [10]. The face recognition process is focused on the training image in every lighting condition.

A. Face Recognition Approach

Many methods have been developed to solve problems that occur in face recognition which are affected by illumination conditions. In its development, these various methods are classified into 3 domains, namely techniques using models, feature classification, and preprocessing techniques.

Model based approaches are based on low-dimensional linear sub-spaces to reduce the effect of illumination on facial images. Some examples of this method include Illumination Cone [11], Spherical Harmonic [12], and so on. The disadvantage of this approach is that many face images are required to construct a linear space, making it difficult to handle large databases.

In features based approaches, the face recognition process uses illumination invariant features. Some examples of this method include 2D Gabor-like Filters [13], Discrete Cosine Transform / DCT [5], Local Binary Patterns [14], and so on.

While the preprocessing approach uses an image normalization process with contrast adjustment on the training image and the test image. The Quotient Image (QI) and Self-Quotient Image (SQI) methods are examples of techniques that use this approach. This technique was developed to improve facial recognition performance which is affected by variations in lighting conditions. The face recognition process by preprocessing using illumination normalization can be seen in Figure 1.

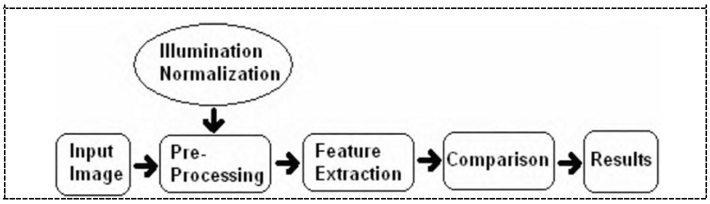

Fig. 1. Face recognition process with pre-processing using illumination normalization [15]

In this study, the Robust Regression method used uses preprocessing approaches. The contrast adjustment process is carried out at the preprocessing stage to produce a normal image contrast. This technique is proven to be able to improve facial recognition performance. Contrast adjustment is required before the classification process, where face image size a x b is first performed normalization of illumination using histogram equalization technique. The classifier machine model is generated through a training process. This engine is needed to generate regressors/predictors. Regressors are created for each person. The next process is the formation of a vector with a smaller dimension. This vector is generated from the previous training image matrix. The maximum value of this vector is 1. Regressors are generated for each individual using a set of several training vectors.

The classification process is carried out after the training stage is carried out. This process classifies the test data into one of the classes using a predictor (generated during the previous training process). The preprocessing step is carried out in the training process and facial image testing. This Robust Regression develops vectors from the test image matrix. This vector has a smaller dimension with a maximum value of 1. The test image class is known based on the Huber estimation results using the smallest distance.

B. Contrast Adjustment

Theoretically, image characteristics are affected by lighting. This lighting can cause changes in the characteristics of the image from its original condition. To reduce changes in this image, a contrast adjustment process is required to normalize the contrast. In face recognition, this contrast adjustment process is carried out at the training stage and at the image classification stage. Contrast adjustment allows the contrast level of all images to be similar so that they are easier to classify. By utilizing this technique, facial recognition performance is expected to be improved.

Histogram equalization method is widely used to adjust image contrast. This study tested this method on the condition of the training image in various lighting variations. The result will be known whether the technique shows a better performance than not using the facial recognition preprocessing technique.

C. Image Dataset

The experiment in this research uses a collection of facial images in the AR Face Database. In this database, each person whose face is photographed contains different facial expressions, illumination conditions and occlusions. Each image is taken using a data acquisition technique under strictly controlled conditions.

The facial images used in this study were 100 people taken from the AR Face Database. All images used are 100x100 pixels in size. The condition of the face image for each person is chosen which has a neutral expression, the object is seen from the front (frontal view), and consists of several varying lighting conditions. The variation of image lighting conditions is divided into 2 sessions. Session in this case is a session in the acquisition of image data in the same position with several different lighting conditions. Each session has 4 variations, namely low lighting conditions (light source from the front with light intensity levels on a low scale), moderate lighting conditions (side light sources with light intensity levels on a medium scale), high lighting conditions (side light source with high light intensity level) and extreme lighting conditions (front light source with very high light intensity level).

TABLE I. EXAMPLE OF A PERSON IMAGE WITH 2 SESSIONS OF LIGHTING CONDITIONS

Lighting Variation	Session 1		Session 2	
	Image Number	Image View	Image Number	Image View
Low	01		14	
Moderate	05		18	
High	06		19	
Extreme	07		20	

The lighting conditions in this study had 2 sessions and 8 variations of a person's facial image as shown in table 1. The testing process in the experiments in this study was carried out in both sessions and then the average accuracy was calculated based on the results in each session. Tests were carried out on each training image lighting condition to determine the effect of contrast adjustment on each of these lighting conditions.

D. Experiment Scenario

Table II shows the test scenarios in more detail. Tests are carried out on the image in each lighting condition in each session. In scenario 1, the training image uses training images 01 and 14 which are in low lighting conditions. In scenario 2, the training image uses training images 05 and 18 which are in moderate lighting conditions. In scenario 3, the training image uses training images 06 and 19 which are in high lighting conditions. While in scenario 4, the training image uses training images 07 and 20 which are in extreme lighting conditions.

Experiments in this study were conducted to determine the performance of the robust regression method for face recognition on variations in training image lighting, with pre-processing using histogram equalization (histeq) technique and without pre-processing (no contrast adjustment process). Furthermore, the results of the two will be compared to find out which one produces better performance.

TABLE II. THE SCENARIO FOR TESTING

Testing Scenario	Images Session	Training Images	Training Images
1	1	01	05, 06, 07
	2	14	18, 19, 20
2	1	05	01, 06, 07
	2	18	14, 19, 20
3	1	06	01, 05, 07
	2	19	14, 18, 20
4	1	07	01, 05, 06
	2	20	14, 18, 19

III. RESULTS

This section describes the results of experiments that have been carried out based on predetermined experimental scenarios. There are 4 experimental results obtained, namely the results of experiments with training images at low, moderate, high, and extreme lighting conditions.

TABLE III. THE RESULT 1

Session	Training Image	Testing Image	Accuracy of Histeq (%)	Accuracy of No Pre-processing (%)
1	01	05	87.00	88.00
		06	80.00	87.00
		07	91.00	84.00
Average Accuracy			86.00	86.33
2	14	18	93.00	96.00
		19	88.00	88.00
		20	94.00	76.00
Average Accuracy			91.67	86.67
Average Accuracy of All Sessions			88.83	86.50

The experimental results in table 3 provide information about the performance of facial recognition with training images in low lighting conditions. In the result on session 1, the histogram equalization performance was lower. Meanwhile in session 2, histogram equalization shows a higher performance. The average performance accuracy of histogram equalization is 88.83%, 2.33% higher than the performance without pre-processing which has an accuracy of 86.50%. This shows that the use of histogram equalization technique for contrast adjustment in pre-processing gives a better performance impact on training images with low lighting conditions, but the effect is still less significant.

Table 4 shows the results of experiments with training images in moderate lighting condition. In session 1 and 2, histogram equalization shows higher performance. The average accuracy of face recognition using histogram equalization is 88.33% and accuracy without using histogram equalization is 74.33%. These results indicate that the approach that uses histogram equalization for contrast adjustment in pre-processing with training images on moderate lighting conditions is better than the approach that does not use histogram equalization, with a significant difference in accuracy of 9.00%.

TABLE IV. THE RESULT 2

Session	Training Image	Testing Image	Accuracy of Histeq (%)	Accuracy of No Pre-processing (%)
1	05	01	92.00	86.00
1	05	06	65.00	54.00
1	05	07	91.00	84.00
Average Accuracy			82.67	74.67
2	18	14	92.00	88.00
2	18	19	67.00	51.00
2	18	20	93.00	83.00
Average Accuracy			84.00	74.00
Average Accuracy of All Sessions			83.33	74.33

TABLE V. THE RESULT 3

Session	Training Image	Testing Image	Accuracy of Histeq (%)	Accuracy of No Pre-processing (%)
1	06	01	87.00	80.00
1	06	05	70.00	45.00
1	06	07	99.00	94.00
Average Accuracy			85.33	73.00
2	19	14	86.00	77.00
2	19	18	60.00	47.00
2	19	20	97.00	85.00
Average Accuracy			81.00	69.67
Average Accuracy of All Sessions			83.17	71.33

Table 5 shows the results of experiments with training images in high lighting condition. In session 1 and 2, histogram equalization shows higher performance. The average accuracy of face recognition using histogram equalization is 83.17% and accuracy without using histogram equalization is 71.33%. These results indicate that the approach that uses histogram equalization for contrast adjustment in pre-processing with training images on high lighting conditions is better than the approach that does not use histogram equalization, with a significant difference in accuracy of 11.84%.

TABLE VI. THE RESULT 4

Session	Training Image	Testing Image	Accuracy of Histeq (%)	Accuracy of No Pre-processing (%)
1	07	01	89.00	90.00
1	07	05	93.00	97.00
1	07	06	100.00	99.00
Average Accuracy			94.00	95.33
2	20	14	87.00	91.00
2	20	18	93.00	95.00
2	20	19	97.00	96.00
Average Accuracy			92.33	94.00
Average Accuracy of All Sessions			93.17	94.67

Table 6 shows the results of experiments with training images in extreme lighting condition. In session 1 and 2, histogram equalization shows lower performance. The average accuracy of face recognition using histogram equalization is 93.17% and accuracy without using histogram equalization is 94.67%. These results indicate that the approach that uses histogram equalization for contrast adjustment in pre-processing with training images on extreme lighting conditions is lower than the approach that does not use histogram equalization, with a not significant difference in accuracy of 1.50%.

IV. CONCLUSION

The experiments carried out in this study provided important results for the development of a facial recognition system. The contrast adjustment process using the histogram equalization method on the training image in low lighting conditions resulted in better facial recognition performance than the approach without using contrast adjustment at the preprocessing stage. However, the difference in performance is not significant. Meanwhile, in medium and high lighting conditions, the contrast adjustment process resulted in significantly better facial recognition performance than the approach without using contrast adjustment in the preprocessing stage.

Contrasting results are shown in extreme lighting conditions, where the contrast adjustment process results in lower facial recognition performance than the approach without using contrast adjustment in the preprocessing stage.

However, facial recognition performance in training images under extreme lighting conditions resulted in very high performance, better than performance in other lighting conditions (low, moderate, and high), whether using contrast adjustment or not at the preprocessing stage.

This study shows the results that provide important information that the contrast adjustment process intended to normalize illumination at the face recognition pre-processing stage is not always effective in all lighting conditions of the training image. In each lighting condition, the training image requires a different approach in handling image contrast so that facial recognition results in better performance.

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