The Face Recognition Performance in Every Lighting Condition of Testing Data

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Abstract. Face recognition system is still a topic that is widely studied today, because it has problems that are quite complex. One problem is related to the illumination factor, which significantly influences face recognition performance. One of the methods often used for object recognition problems that is influenced by illumination factors is the robust Regression, which is also used in this research. The problem to be solved is related to the performance of face recognition in various lighting conditions. Using one of the face databases, the Yale Face Database B Cropped, an experiment was performed on each lighting condition of the face data. In the Yale Face Database B Cropped, there are 10 individuals, where each individual has 64 variations of images based on illuminations which are grouped into 5 subsets according to their contrast level. Experiments are generally carried out using all subsets as training data and all other data as testing data, where the results show general face recognition performance (in all lighting conditions). In this research, experiments were carried out for each subset as testing data, where the results showed the performance of face recognition in each lighting condition. The experimental results showed the highest face recognition performance in subset 1 (98.21%), while the lowest performance is in subset 4 (84.46%). The trend of the experimental results shows that the face recognition performance of the Robust Regression method is getting better on face data with a higher level of contrast.

Keywords: Face Recognition, Robust Regression, Lighting Conditions, Yale Face Database B Cropped.

1. Introduction

Biometric technology is currently widely used to recognize a person's identity automatically. Recognition of individual identity is very important especially in environments that require limited access for the authentication process and granting access rights [1]. For security purposes, this technology is also increasingly needed, because it can support the monitoring process more effectively. In its implementation, this technology is a better alternative than using passwords or PINs that can be hijacked by others.

Biometric technology that is widely implemented today is fingerprints, retina of the eye, face, and other physical characteristics of humans. Various equipment is currently equipped with this technology, for example laptops, cellphones, special room doors, and so on. Thus, the potential for misuse or illegal access to these important assets can be avoided. In this research, one of the biometric
Finally, the problem to be solved in this research is about the performance of face recognition in various lighting conditions. Theoretical variations in lighting on the face produce varying degrees of face image contrast as well. So that the performance of face recognition systems would certainly be varied as well. In this research, empirical testing will be carried out to determine the performance of the face recognition system in each face object’s condition based on the lighting conditions.

2. Methodology

Face recognition system in this research uses the Robust Regression method. Empirical experiments were carried out using one of the standard face databases, the Yale Face Database B Cropped.

2.1. The Face Recognition Method

This method builds classifier model that produces a regressor / predictor for each individual. At the pre-processing stage, each face image is normalized using the histogram equalization technique [15]. This pre-processing stage is very important to do to reduce the effects of lighting variations which become difficult problems in image processing [16][17]. Furthermore, the image matrix is converted into a smaller dimension vector with a maximum value 1 and makes a regressor / predictor for each class using a combined vector of the training image.

In order to recognize individuals at the testing stage, the classification process is carried out on the test data into one of the classes using a model or predictor that has been made. In the pre-processing stage, the illumination normalization is carried out using the histogram equalization technique. Furthermore, the testing image matrix is converted into a smaller dimension vector with a maximum
value 1 and the testing image class is predicted using the results of the Huber estimation with the smallest distance.

2.2. Dataset

One of the standard face databases widely used by researchers is the Yale Face Database B [18]. The images in this database have the severity of lighting in most of the images [19].

In this research, all images in this database are cropped in a minimal area of the face (between eyes to mouth), which is then called Yale Face Database B Cropped. Figure 1 is an example of face images from the same individual in Yale Face Database B (Figure 1.a) and Yale Face Database B Cropped (Figure 1.b).

![Figure 1. Examples of a face image from the same individual in Yale Face Database B and Yale Face Database B Cropped](image)

The dataset used in this research consists of 10 individuals in a neutral / frontal position (shooting from the front). Each individual consists of images with 64 variations of illumination, as shown in Figure 2. The variation of illumination on the face image is caused by the angle of illumination on the various face objects. The illumination angle (the direction of the light source that illuminates the object's face) is a very important factor that affects the face image [20].

![Figure 2. One of the individuals in Yale Database B Cropped with 64 variations of illumination in a neutral / frontal position](image)
Each individual with 64 variations of illumination is grouped into 5 subsets according to the level of contrast (Table 1). This level of contrast in face images is the result of varying lighting conditions.

| Subset  | Lighting Angle | Number of Images | Image Number | Lighting Condition | Average of Contrast |
|---------|----------------|------------------|--------------|--------------------|---------------------|
| Subset 1| 0-12°          | 7                | 01-07        | Very Normal        | 102.14              |
| Subset 2| 13-25°         | 12               | 08-19        | Normal             | 85.63               |
| Subset 3| 26-50°         | 12               | 20-31        | Moderate           | 67.79               |
| Subset 4| 51-77°         | 14               | 32-45        | Extreme            | 47.98               |
| Subset 5| > 77°          | 19               | 46-64        | Very Extreme       | 20.00               |

### 2.3. Experiment Scenario

The experiments in this research were carried out using a subset as testing data and all other subsets as training data. The results show the performance of face recognition under lighting conditions in a subset.

In experiment scenario 1, subset 1 becomes testing images, while subset 2-5 as training images. In experiment scenario 2, subset 2 becomes testing images, while subsets 1, 3, 4, and 5 become training images. In experiment scenario 3, subset 3 becomes testing images, while subsets 1, 2, 4, and 5 serve as training images. In experiment scenario 4, subset 4 is testing images, while subsets 1, 2, 3, and 5 are training images. In experiment scenario 5, subset 5 becomes testing images, while subset 1-4 as training images. Based on the 5 experiment scenarios, it will be known the performance of face recognition in every lighting condition.

### 3. Experiments and Results

This section describes the results of experiments that have been carried out. Face recognition performance in the form of an accuracy level of each testing process carried out on testing images.

Based on experiment scenario 1, face recognition performance reached 98.21% (table 2). In this very normal lighting condition, the face recognition performance is quite high.

| Evaluation Techniques | Training Images | Testing Images | Accuracy (%) |
|-----------------------|-----------------|----------------|--------------|
| 1                     | Subset 2        | Subset 1       | 100          |
| 2                     | Subset 3        | Subset 1       | 100          |
| 3                     | Subset 4        | Subset 1       | 92.86        |
| 4                     | Subset 5        | Subset 1       | 100          |

Average Accuracy 98.21

Based on experiment scenario 2, face recognition performance reached 93.75% (table 3). In these normal lighting conditions, the face recognition performance is lower than in very normal lighting conditions.

Based on experiment scenario 3, face recognition performance reached 91.88% (table 4). In these moderate lighting conditions, the face recognition performance is lower than in very normal or normal lighting conditions.
Table 3. The Experiment Result 2

| Evaluation Techniques | Training Images | Testing Images | Accuracy (%) |
|-----------------------|-----------------|----------------|--------------|
| 1                     | Subset 1        | Subset 2       | 100          |
| 2                     | Subset 3        | Subset 2       | 100          |
| 3                     | Subset 4        | Subset 2       | 77.50        |
| 4                     | Subset 5        | Subset 2       | 97.50        |
| Average Accuracy      |                 |                | 93.75        |

Table 4. The Experiment Result 3

| Evaluation Techniques | Training Images | Testing Images | Accuracy (%) |
|-----------------------|-----------------|----------------|--------------|
| 1                     | Subset 1        | Subset 3       | 95.83        |
| 2                     | Subset 2        | Subset 3       | 94.17        |
| 3                     | Subset 4        | Subset 3       | 90.83        |
| 4                     | Subset 5        | Subset 3       | 86.67        |
| Average Accuracy      |                 |                | 91.88        |

Based on experiment scenario 4, face recognition performance reached 84.46% (table 4). In these extreme lighting conditions, the face recognition performance is lower than in very normal, normal or moderate lighting conditions.

Table 5. The Experiment Result 4

| Evaluation Techniques | Training Images | Testing Images | Accuracy (%) |
|-----------------------|-----------------|----------------|--------------|
| 1                     | Subset 1        | Subset 4       | 73.57        |
| 2                     | Subset 2        | Subset 4       | 79.29        |
| 3                     | Subset 3        | Subset 4       | 87.14        |
| 4                     | Subset 5        | Subset 4       | 97.86        |
| Average Accuracy      |                 |                | 84.46        |

While based on experiment scenario 5, face recognition performance reached 95.79% (table 6). In this extreme lighting condition, face recognition performance is quite high, but still low compared to very normal lighting conditions.

Table 6. The Experiment Result 5

| Evaluation Techniques | Training Images | Testing Images | Accuracy (%) |
|-----------------------|-----------------|----------------|--------------|
| 1                     | Subset 1        | Subset 5       | 92.11        |
| 2                     | Subset 2        | Subset 5       | 92.63        |
| 3                     | Subset 3        | Subset 5       | 98.42        |
| 4                     | Subset 4        | Subset 5       | 100          |
| Average Accuracy      |                 |                | 95.79        |
4. Conclusion

The experimental results showed the highest face recognition performance in subset 1 (face data with very normal lighting conditions), namely 98.21%. While the lowest performance in subset 4 (face data with very normal lighting conditions), which is 84.46%.

The trend of the experimental results shows that the face recognition performance of the Robust Regression method is getting better on face data with a higher level of contrast. But at a very low contrast level (very extreme), the face recognition performance is actually relatively high.

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