Modelling of Facial Images for Analysis of Recognition System

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Abstract. Face recognition is categorized as a biometric technology that employs the use of computer ability in image processing to detect and recognize human faces. Face recognition system has numerous applications for many purposes such as for access control, law enforcement and surveillance thus this system is dominant in present technology. Generally, face recognition system become more advance in term of the accuracy and implementation. However, there are a few parameters that effects the accuracy of recognition system for examples, the pose invariant, illumination effect, size of image and noise tolerance. Even though there are a number of systems were already available in the literature, the complete understanding of their performances are relatively limited. This is due to many systems focused on a narrow application band – therefore, a comprehensive analysis are needed in order to understand their performances leading to establishing the conditions for successful face recognition system. In this paper we developed a synthetic model to represent facial images to be used as a platform for performance analysis of facial recognition systems. The model includes 5 face types with the ability to vary all parameters that are affecting recognition performance – measurement noise, face size and face-background intensity differences. The model is important as it provide an avenue for performance analysis of facial recognition systems.
1. Introduction
Face recognition system is a biometric technology that uses the human face as the subject to recognize and identify the human information. Among other biometric recognition systems such as fingerprint, iris and voice recognition, face recognition is the quickest and easiest way to use for identification purposes. The face recognition system is categorized as part of the image processing as it implements the computer ability in order to conduct the recognition process. Face recognition is preferred widely in use alongside current technologies for example surveillance and security cameras [1]. Moreover, the face recognition system can be used to prevent crime, monitoring people plus for personal access pass. The application is easier to be implemented due to simple and lower cost for installation.

Face recognition began in early 1964, where the American researchers, Woodrow Bledsoe et al. explored computer programming on facial recognition [2]. In 1988, Linear Algebra was launched and being used to interpret data related with the face recognition process by the present artificial intelligence approach thus it eases the operation for the system[2]. Deep Learning [3] that implements the machine learning method on artificial neural networks was introduced in 2011. This method has improvised the face recognition system making it easier to be used. Facebook has discovered a new algorithm, Deep Face in 2014 where the approach achieved higher performance of eyes detection until 97% accuracy[4]. As time changes, the technology of face recognition enhances the improvement and raises a higher standard of implementation.

Generally, face recognition has three main processes which are face acquisition, face detection and face recognition [5]. Every process is crucial for a face recognition system. At the face acquisition stage, it is the beginning process for the system where it needs to obtain an image of human face[6]. Then followed by a face detection process which plays an important role after the face is acquired. At this stage, it will undergo a few more processes such as facial localization and feature extraction. There are many approaches on facial localization and one of the example s is by using a segmentation approach. With this method, the system can identify facial parts like eyes, nose and lips as the facial key points[7]. For feature extraction, it is applied to interpret the input image into simplified form and usually it will differentiate the frontal face and background from the image. Feature extraction process has become a crucial element in image processing especially for performing object detection. Face recognition is the final process for the system where at this stage the system will do classification and decision making to interpret the output. There are many existing algorithms for face recognition systems for instance, 3D recognition [8], feature-based [9] and skin texture analysis [10].

On the other hand, there are some challenges in performing face recognition. The variation of scene and image parameters can affect the detection and recognition process and this includes the factor of illumination effect [11], size of face in image, noise tolerance [12] and pose invariant. All these parameters undergo the nature environment effect that will provide difficulty during the face detection process and the accuracy for the face recognition system obviously. So, the condition for every parameter needs to be considered to achieve a successful recognition approach. Currently, the condition for successful recognition has yet to be established and the analysis is limited to other applications such as motion segmentation [13, 14], image thresholding [15] and sign language [16].

In this paper, synthetic models have been developed to represent facial images. The model portrayed five different types of face shape and based on the face features as eyes, nose and lips. Additionally, the scene parameters of facial images – intensity, size and noise can be varied using the synthetic model. These synthetic models are useful as they can served as an avenue for performance analysis of facial recognition systems.

2. Modelling of facial image
The modelling process steps of facial image is shown in Figure 1. Basically, there are two main steps in developing synthetic models to represent facial images.
2.1. Modelling of facial images
The modelling of facial image starts by creating synthetic images with different types of faces and facial features measurement. In fact, there are various types of human faces in terms of shape, size and facial measurements. There are a few researches related with the study of human face and mostly addressing that there are commonly 5 types of human face shapes. Figure 2 shows the basic shape of human faces. These shapes are considered in creating the synthetic image representing the face model.

The synthetic face is a matrix with a dimension of 360x240 thus there are a total of 86400 data for a single image. The data indicate total pixels of the synthetic image. Inside the matrix data, it consists of three different variables declared with separate values. The variables are the letter of 'b' indicates the background of the image, 'f' represents the foreground which specified for frontal face and 'p' declares all of the facial features.
Figure 3. Synthetic model images

Figure 3 shows five synthetic images that have been developed. These synthetic images are in the form of grayscale representation where the pixels are valued at the range of 0 until 255. The five basic shapes of faces are round, oval, square, heart and oblong have been considered in the development of facial images. The synthetic images represent the face shapes as below,

- Image A – round face
- Image B – oval face
- Image C – square face
- Image D – heart face
- Image E – oblong face

2.2. Varying the scene parameters

The synthetic models will be tested under three parameters, as adding noise, manipulating the pixel intensity and changing the size of the frontal image. The first process is manipulating the intensity difference between object and background image from 10% to 100%. Next, the object size is varied from 10% to 100%. Then, the process conducted is adding noise to the input models. The Gaussian noise is added with the mean = 0 but with different variance, $\sigma^2 = 0.1$ until 0.5. Then, the intensity difference between object and background is varied from 10% to 100%. Next, object size on the synthetic image also varies from 10% to 100%.

These synthetic images were developed to represent scene parameters that will serve as input images. The parameters were varied by altering the characteristics of images, as follows:

- Intensity of pixels refers to the difference between the foreground (frontal face) and background of the image is varied from 10% to 100%. If the pixel intensity of a grayscale image approaches the limit range of 255, it will assigned as the maximum grey level value of 255. For example, at an intensity different of 100%, the foreground value might be higher than 255 however it is assigned to be levelled at 255. In this case, the difference in intensity between background and foreground pixels indicate the lighting condition of the scene.

- Object size for input image is varied from 10% to 100%, where 100% represents the largest frontal face that almost occupies the whole image. But, the face is very small and difficult to see at scale of 10%. Object size represents the face location and its distance from the camera.

- Noise level is measured by the value of variance which denotes by $\sigma^2$. A standard normal distribution of Gaussian noise is added into the input image. This experiment is carried out by using the level of noise at $\sigma^2 = 0.1$ until 0.5. Basically, the noise measurement represent the quality of the input image.
In total, the synthetic model contains 2500 images from 5 face types with variation of 10 levels of intensity differences, 10 levels of object size and 5 levels of measurement noise. The number of images could be increased with additional levels of variation accordingly.

3. Results

There are a few parts in this experiment. In this section, it will discuss the results obtained from the test performed on a few images with different face shapes and measurements as the input model.

3.1. Effect of intensity difference

The first parameter being tested is the intensity difference of input models. Intensity difference refers to the ratio of pixel values between background and object (frontal face). Besides, all of the pixels that represent the facial features such as eyes, nose and lips are also being considered. Typically, the frontal face pixels have a higher value of gray level compared to facial features and background pixels. This test varied at an intensity difference of 10% to 100%. The results can be observed from Figure 4.

![Figure 4. Effects of intensity difference at 10% to 100% in round face](image)

The results of Figure 4 indicate the influence of intensity difference on input model. At lower intensity of 10%, the face is not able to be observed clearly because the difference of pixel intensity between background and frontal face is just slightly differ. Hence, the frontal face and facial features are difficult to detect. Increasing the intensity difference will produce a better output as the image showed clearly the separation of background and object pixels. However, at intensity of 100%, the facial features disappear because the pixels are at the highest value of 255 in grayscale representation thus it will be classified the same as frontal face pixels.

These intensity parameters represent the lighting conditions of the scene that resulted in the input image. When the intensity difference is very low, the image is considered underexposure because it appears darker. However, at a certain condition where the image has an extreme intensity difference, it is known as an overexposure image. For overexposure images, the image looks too bright to a point it is unpleasant looking. So, this parameter of intensity is known to be one of the factors affecting the face recognition system.
3.2. Effect of face size

Next, the test on the varied size of the object which refers to the frontal face has been performed. The size of input image is varied from 10% to 100% and the results are shown in Figure 5. The size obviously represents the location and distance of the face from the camera.

![Figure 5. Effects of size for 10% to 100% in oval face](image)

These object size settings were changed 10% to 100%. When the size of the object is smaller, it depicts a smaller face on the entire image, with the background pixels are greater than the frontal face as observed in Figure 5 for the size of 10%. When the size is set to 100%, a larger face is displayed that almost occupies the entire image.

3.3. Effect of measurement noise

The noise was then added to the input model to determine the effects. In this investigation, Gaussian noise with mean value of zero is selected with different variance. Figure 4 shows the results of adding noise with a variance ranging from 0.1 to 0.5.

![Figure 6. Effects of adding noise 0.1 until 0.5 in square face](image)

From Figure 6, when adding noise, $\sigma^2 = 0.1$, the frontal face and facial features can be recognized. However, as the noise variance increases, the frontal face and facial features become more difficult to
recognize as shown in the output when the noise variance of $\sigma^2 = 0.5$. The noise measurement represents the quality of the input image, where basically the noise changes the nature of the original image.

4. Conclusion
Synthetic models have been developed to represent facial images. The model portrayed five different types of face shape and based on the face features as eyes, nose and lips. Additionally, the scene parameters of facial images – intensity, size and noise can be varied using the synthetic model. These synthetic models are useful as they can serve as input for performance analysis of facial recognition system. In total, the synthetic model contain 2500 images from 5 face types with variation of 10 levels of intensity differences, 10 levels of object size and 5 levels of measurement noise. The number of images could be increase with additional levels of variation accordingly.

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