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Face Region Detection Using Skin Region Properties

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ABSTRACT

Face detection is an important step in face image processing. This paper presents an efficient method to detect the face region based on skin region properties. Skin detection and morphological operations are used to detect roughly skin regions. The properties of these regions are used to detect the face region and discard other regions automatically. More refining is applied to isolate the face region by removing the neck and forehead. Experiments with different images of different subjects show that the proposed technique is able to discover the face region faster with a high detection rate. Different races and subjects with different occlusions such as wearing glasses or having beards/ moustaches, etc. were tested with good results obtained.

Keywords: Face detection, Skin detection, Normalized space colour, Thresholding, Morphological operation and Properties of regions.

1. INTRODUCTION

Face image detection, analysis and recognition have become active research topics in many disciplines such as computer science [10] and medicine [7].

Although, face detection is one of the challenging problems in image processing and in building systems that perform face recognition, it is essential in applications such as video surveillance, and human computer interface. Yang [11] stated that the challenging factors related to face detection include the pose, structural components, facial expression, illumination, occlusion, and image quality of the subjects. For example, with respect to the pose of the subject, the position of the face can cause some parts of the face such as eyes and nose to be occluded in the captured image. In terms of the structure components, features such as beard, moustache and glasses, may not result in the correct face detection as these are subject to change. Similarly, individual affective nature changes with time could cause some difficulties in the machine's correct identification.

It is observed that, the skin colour in images changes with light sources and illumination conditions [9]. This is one of the main problems in face detection. The other problem includes occlusion where faces may be partially occluded by other objects such as scarves, hats, etc. Similarly, some faces may be occluded by other faces in an image of a group of people.

According to Espinosa [3] the classical face detection system can be decomposed into several stages: *image acquisition*, *image pre-processing*, *feature extraction* and *classification*. In the image acquisition stage, the captured images are obtained from a camera. This is followed by the image pre-processing stage where the captured images are enhanced by eliminating noise and to reduce the complexity for later processing. The feature extraction stage detects and extracts the features from the regions. Finally, the classification stage classifies the regions into face and non-face areas.

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Many methods have been proposed to address the problem of face detection. The idea of face detection is to identify the face regardless of changes in lighting conditions, poses and facial expressions. Although existing techniques are not appropriate for images that have a combination of occlusions as mentioned above, most of the face detection techniques initially identify the face skin region before the face is finally classified. Furthermore, most of face detection and recognition algorithms assume that a face exists in the image in order to classify as the face and non-face regions [5, 2].

As cited in Nallaperumal [8], face detection techniques can be categorised into four categories: *knowledge-based*, *facial feature-based*, *appearance-based* and *template matchingmethods*. The details of these methods are description in [4, 11].

Knowledge-based method depends on using rules of facial features to detect the face. Rules capture and describe the relation between the features of a face. This method is suitable for front images but has difficulties in detecting faces in different postures. The method translates the human knowledge to well-defined rules. If the rules are more general, they may fail to detect the right face. However, if the rules are not more specific, they may fail to detect some faces [1, 2].

*Facial feature-based method*is used to find facial features that are not affected by posture, light conditions or other factors. Some researchers have introduced methods to locate invariant features on the faces such as mouth, nose, eyes, and eyebrows [12]. However, such features can be easily depraved by illumination, noise (occlusion) and pose.

Appearance-based method is based on the use of techniques from statistical analysis and machine learning to compute facial features in order to determine if there is a face or not. It uses the models learned from a set of training images, where the intensity is the main key for the detection. Therefore, the method is not sufficient to detect the face with images that have poor quality intensity and some occlusions [1].

*Template matchingmethod*is used to detect an individual face in images for face localisation and detection. The idea of template matching is to compute the correlation between the pattern with the given image and template patterns of the face so as to determine whether it is a face or not.Manoria [6] used a template face to determine if the segmented region is a face or not. The template matching method is a well known technique that can be applied on images containing more than one face.

Although research has been done in this area using different methods, the problem of face detection needs further investigation as it is one of the fundamental problems in computer vision. Some recent control methods are described in [13-20].

The main objective of this work is to propose a face detection algorithm that is applicable to frontal view of the face under normal lighting conditions.

Our face detection system works on the whole image, looking for skin regions that satisfy the skin detection algorithm using normalized colour space and Gaussian distribution.

This is followed by face detection algorithm that utilises and examines the skin regions' properties, where the image's background has been eliminated. This algorithm allows us to discard any region other than a face. Images have been tested using different races with occlusions such as wearing glasses and/or having a beard and/or moustache. Results achieved with this algorithm show a high rate of detection and accuracy.

2. FACE REGION DETECTION

Face regions are detected in three steps. Firstly, the skin-like regions are verified by analysing the skin colour tones. Secondly, the skin regions are verified to identify whether they show a face or not based on the region properties such as ellipse and box elements. Finally, the face region is refined if the high to width ratio of this region satisfy the golden ratio $\left(\left(1+\sqrt{5}\right)/2\right)$.

2.1. Skin-like Region Detection

Skin colour detection is the first step in skin segmentation and the most important process in the human face detection. Skin colour information is used to detect and track human faces from a complex background. Different people have different skin colours though the major difference lies largely between their intensity rather than their chrominance [11]. Possible skin-like regions are detected within the input image utilising the skin detection algorithm proposed by Maruf and Rezaei [7].

The skin colour model developed is based on normalized RGB colour space derived from the RGB components [11] as shown in equations 1, 2, and 3 respectively. The chromatic colour is called 'pure colour' in the absence of luminance. The *b*-component of chrominance is omitted as it does not have any significant information and thus reducing the spatial dimension. The summation of the three chromatic colours is to one ($r + g + b = 1$), where r and g represent the pure colour and contain the whole information about the chromatic value.

$$r = \frac{R}{R+G+B} \tag{1}$$

$$g = \frac{G}{R+G+B} \tag{2}$$

$$b = \frac{B}{R+G+B} \tag{3}$$

In this work, two skin colour models are applied, which are Gaussian and Likelihood models using the normalised RGB according to equations 4 and 5 respectively. Each model is built independently, and then the results are compared for the accuracy and computational speed.

$$P\left(X/skin\right) = \frac{1}{2\pi\left|\sqrt{\sigma}\right|} e^{\left(-0.5*\left(X-\mu\right)^T \sigma^{-1}\left(X-\mu\right)\right)} \tag{4}$$

$$P\left(X/skin\right) = e^{\left(-0.5*\left(X-\mu\right)^T \sigma^{-1}\left(X-\mu\right)\right)} \tag{5}$$

Firstly, the skin-training model is constructed from a total of 200-skin colour samples from 200 images captured in the laboratory using a digital camera. These are used to build up the colour distribution of human skin in a normalised colour space and to establish the skin training model. Laboratory images are captured from different genders, ages and ethnicities using the camera in normal lighting conditions.

The mean and covariance of the skin training model are substituted into Gaussian and Likelihood models to obtain the segment skin. For each input image the normalised colour space is achieved and the skin-like region is computed using the Gaussian and Likelihood model.

The result obtained from the Likelihood model is more accurate and computationally inexpensive, where every pixel can be classified as skin or non-skin. Figures 1a and 1b show a test image that is segmented to skin and non-skin regions using the Gaussian and Likelihood models.

Figure 1: (a) Image segmentation into skin and non-skin regions based on Gaussian model.

Figure 1: (b) Image segmentation into skin and non-skin regions based on Likelihood model Likelihood model

2.1.1. Thresholding and Morphological Operations

As skin colour varies from person to person, the image is segmented into a binary image using the threshold technique. The threshold value ranges from 0 to 1 incremented by 0.05 to select the optimal threshold experimentally. The best threshold value is selected when the number of skin segments is set to minimum. Figure 2a shows the skin-likelihood with optimal threshold value.

Noise can corrupt the output image. This noise may appear as a small hole in the skin region. The face detection algorithm involves morphological operations to refine the skin-like regions extracted from the skin segmentation process. The facial region can contain some small holes as a result of certain features such as eyes and mouth.

The sub-regions can be grouped together by using the simple dilation and erosion operations on the regions. The dilation is to fill any small hole in the region and erosion to remove any small object from the background.

The problem may occur when this technique is applied to images containing a group of people as the detected region might appear as a single entity. The proposed algorithm assumes that only one face is shown in an image and, therefore, using these operations will lead the skin detection to be more accurate. Figure 2b shows the final skin-like regions in the input image after applying the Morphological operations.

Figure 2: (a) Image segmentation with optimal threshold value.

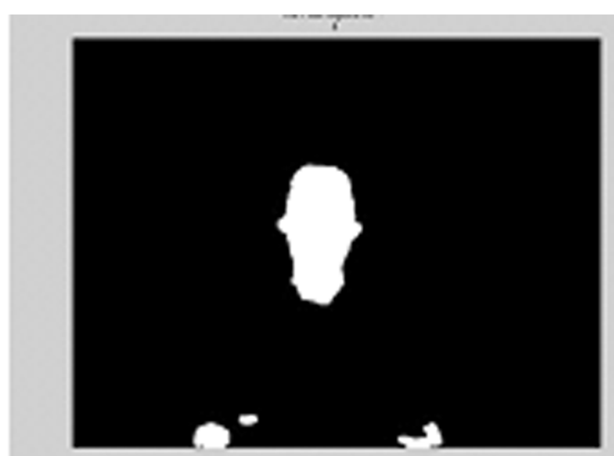

Figure 2: (b) The skin-like regions in image after the Morphological operations

2.1.2. Face Region Detection

The purpose of the face region detection is to eliminate the background and non-skin areas. In this stage, the identified regions determine the existence or absence of a face. The algorithm discards any skin region other than a face. Therefore, it is required to identify the face where every pixel in the image is classified as a skin pixel. The next step categorises the skin pixels in different groups. This will signify some meaningful groups such as face and hands.

Face region detection is accomplished by using skin region properties which are ellipse and box regions, and the centroid point of a region.

Every region is labelled based on the binary skin region from the previous stage. Each pixel in the region is examined with 8 of its neighbour's pixels and marks them if they are similar to this pixel. If any neighbouring pixel is marked, then it will be labelled with the current label. When the regions are labelled, each one is examined separately to identify if it is a face region or not based on its properties.

Most of the face detection algorithms are based on skin region segmentation and classify the region as a face if it has at least one hole. However, the face detection can fail when the morphological operations are applied [6].

The proposed algorithm scans the skin segmentations in the image for the possibility of a face based on the ellipse region properties. Properties of the regions are derived experimentally and used to detect and filter the face regions. The face region is detected when the ellipse ratio ranges from 1.0 to 2.2. Also, the major and minor of the ellipse are scaled at least 150 and 100 pixels, respectively. Figure 3 shows the original image and the face region detection.

2.1.3. Refining Face Region

The face skin region is refined to reduce the negative facial detection that considers the neck or forehead as sub-regions of the face. This helps in obtaining a more accurate result and to reduce the computational cost of future stages.

The final face region is cropped based on the following process:

1. Initially determining the centroid point of the face region. Then the box ratio of the face region is calculated.
2. If the box ratio is more than the golden face ratio as approximated in $\left(1+\sqrt{5}\right)/2 \approx 1.618$ and the ellipse ratio ranges between 1.8 and 2.2, then the region box is adjusted by shifting up the high box and the centroid region. As a result, the unnecessary skin, such as forehead and neck, is reduced.

Figure 3: (a) Original Image

Figure 3: (b) Face region detection

Figure 4 shows the new face detection after the shifting up operation. (a) The face region, (b) The grey face with centroid point, (c) The face colour with centroid point, and (d) The cropped face.

3. EXPERIMENTAL RESULTS

In this work, experiments were carried out under the following conditions:

- Only the frontal views of the faces in the single images are analysed.
- Images of individuals are captured from the same distance and with normal room lighting conditions.

A large number of images are applied with different races, ages and gender. No constraints have been imposed on the face such as glasses, beard or moustache.

The mean and covariance of the skin training model are substituted into Gaussian and Likelihood models to obtain the segment skin. Experimentally, the Likelihood model was more accurate and less computationally intensive compared with Gaussian model. The result is robust over the Likelihood model to transform the colour image into greyscale one. Furthermore, the Likelihood model was more robust against black skin. The detection ratio for black skin was 96.67% accurate and 100% for other skins. The appropriate threshold is averaged to threshold the greyscale image and further transformed it to binary image. The skin region detected when the threshold value was 0.25. The skin regions were refined by applying erosion and dilationoperations. The best result obtained when holes of the binary image filled 4-connection pixels, followed by 6-connection pixels erased to remove the noisy background. Then, 8-connection pixels dilated to fill up any small hole. For each image, the number of skin-like regions computed and each region is examined to determine if it is a face or not. The face skin regions detected and disregarded any skin region other than face skin region according to the ellipse of skin region ratio.

The face region is accurately detected even when it contained occlusions such as glasses or facial hair. The face detection rate computed is 98.7% based on a sample of 330 images. A 99% rate of detection was measured from 100 video clips.

(a) (b) (c) (d)

Figure 4: The final facial detection

Prior to the experiment the face skin region was refined to remove unwanted regions such as neck and forehead. Further restrictions such as ellipse and box ratios to the face regions were applied to allow the algorithm to eliminate the unwanted body parts. This reduces the complexity of the computations in the facial feature localization stage.

4. CONCLUSIONS AND FURTHER WORK

In this paper a simple and efficient detection method for detecting faces in colour images is proposed. The detection algorithm is presented in two sections: *skin segmentation*, and *face detection*. Skin segmentation is implemented by building a skin colour model based on normalised colour space. The Likelihood model is used to calculate the probability of skin tone and morphological operations are applied to greyscale images to find the proper skin regions in the images. The proposed face detection algorithm is then applied to the skin regions based on their properties. The advantage of this algorithm overcomes some of the occlusion problems associated with faces.

Further work is ongoing to extend capability of the existing facial feature extraction methods to recognise expressions.

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