Age Estimation In Facial Images Using Angular Classification Technique

A Deepa and DrT. Sasipraba

1Research scholar, Sathyabama University, Department of Computer science & Engineering, Chennai, India
2Dean, Sathyabama University, Chennai, India

ABSTRACT

Background: Facial Aging is a new dimension that has wide range of real world applications in human computer interactions. Face recognition is an important area of biometrics which is of great use in our daily life. It is used for identification of documents such as land registration, passports, driving licenses, recognition of a human in a security area. Face images are being increasingly used as additional means of authentication in applications of high security zone. With progression of age the facial features changes and it is necessary to update the database very often. If we come up with a mechanism that identifies a person in spite of the aging, then this tedious task can be avoided. Aging of face in computer vision studies has multi dimensional challenges; various factors are to be considered for an efficient estimation. This paper discusses about the steps in estimating the age by taking into consideration of increasing the number of age groups to provide a more relevant age from the given facial image. Results: After the features are considered the age is estimated by using ANFIS method. The outputs of the classification are applied to ANFIS and the functions are derived. From these member functions, every image is assigned relatively an age from the stored results The age can be computed by reducing the ambiguity of margin ages. Conclusion: Current face recognition technology has evolved to the point where its performance allows for its deployment in a wide variety of applications. These applications typically ensure controlled conditions for the acquisition of facial images and, hence, minimize the variability in the appearance of different (facial) images of a given subject. Commonly controlled external factors in the image capturing process include ambient illumination, camera distance, pose and facial expression, etc. In this paper a method for estimating age group is analysed. The proposed technique provides a robust method for classifying the age group of the subject from the given scene image. For eye detection and eye ball detection, the face in the image should be without spectacles. Based on classified age group, the group specific features are extracted and are used for age estimation. This reduces the computation load on the system and requires less system resource, providing an efficient, robust and speedy automatic age estimation system which can be used in various applications from web cam based system to high end biometric accesses.

INTRODUCTION

Recent face recognition technologies provide improved performance which paves way for its deployment in a wide variety of applications. These applications ensure controlled conditions for the obtaining the facial images and, there by minimizes the variability in the appearance of different (facial) images of a given subject. Commonly controlled external factors in the image capturing process include ambient illumination, camera distance, pose and facial expression, etc. In these controlled conditions, state-of-the-art face recognition systems are capable of achieving the performance level which can match that of the more established biometric modalities, such as fingerprints, as shown in a recent survey (Gross et al., 2004; Phillips et al., 2007).

Challenges In Face Recognition:

Most of the existing face recognition techniques used in controlled systems deteriorate in their performance when used in uncontrolled environments. Appearance variations caused by pose-, expression-and most of all illumination-changes are challenging problems in the most advanced face recognition approaches. In fact, the
illumination-induced variability in facial images is larger than the variability induced by the subject’s identity. The images of different faces seems to be similar than images of the same face captured under illumination variations. Due to these variations in illumination, numerous approaches have been proposed.

**Limited inter-age group variation:**
In certain cases differences in appearance between adjacent age groups are negligible, causing difficulties in the process of age estimation. This problem is escalated when dealing with mature subjects.

**Diversity of aging variation:**
Both the rate of aging and type of age-related effects differ for different individuals. For example the amount of facial wrinkles may be significantly different for different individuals belonging to the same age group. Due to the diversity of aging variation, the use of the same age estimation technique for all facial subjects may not produce adequate performance. Several factors could influence the aging process. It includes race, gender and genetic traits. So different age estimation approaches are required for different groups of subjects.

**Data availability:**
The development of accurate age estimation systems requires the existence of appropriate datasets suitable for training and testing. Suitable datasets should contain multiple images showing the same subject at different ages covering a wide age range. Since aging is a type of facial variation that cannot be controlled directly by humans, the collection of such datasets requires the use of images captured in the past. The datasets MORPH and FG-NET fulfills all requirements for a dataset suitable for age estimation experiments because the MORPH database contains only few samples per subject whereas the FG-NET database contains images displaying significant non-aging related variation.

**Proposed Scheme For Facial Age Estimation:**

![Proposed Scheme For Facial Age Estimation](image)

**Fig. 3.1:** Steps in facial age estimation

The steps involved in estimation of age from a human facial image are illustrated in Figure 3.1. A human facial image as obtained is subject to preprocessing. The processed image is then categorized into one of the five age group buckets using angular classification technique which is discussed in section 4. Based on the buckets the essential facial features are extracted for refined age estimation. This paper discusses about the preprocessing and classification steps in detail.

**A. Preprocessing:**
The preprocessing step takes an input sample, processes it and returns it as an output, which will be used as an input to another function. The amount and kind of preprocessing done depends on that function. In the particular case of image processing, the preprocessing step may include detecting a specific object in the whole image, adapting the image by rotating, cropping, equalizing... so the feature extraction becomes easier. In order to make the feature extraction step easier, a set of functions has been utilized for preprocessing. The preprocessing step follows the scheme shown in Figure 3.2.

![Proposed Scheme For Facial Age Estimation](image)

**Fig. 3.2:** Preprocessing scheme

**B. RGB to GRAY:**
Define The first step is to convert the input images from RGB to grey space (or capture it directly in grey space if possible). The transformation from RGB to grey space is done using Matlab function Y_image=rgb2gray(RBG_image).

Even though the color information is useful for classifying, we decided not to use it, so we can have a faster system (the carried information is one third of the original amount) and almost as good as if we had the color information.
C. Face Detection:

Face detection is used to determine whether there is a human face in the captured image. The human face is infrared with the presence of facial features such as eyes, nose, mouth, etc. The identification of human face is done using direct image processing techniques which determines the locations and sizes of the face in the image, and separates them from other non-face objects and distracting background information. The face alignment which involves translation, rotation, and scaling is carried out using the center or edges of the eyes as a reference point since the eyes are an important feature that can be consistently identified.

Fig. 3.3: Face detection from given image

In Figure 3.3 the input color image is transformed into a grayscale image. Face localization is applied to determine the position of a face in the image. When the face image is detected, eyes detection is applied to detect the presence and location of the eyes in an image. The eyes location is used for face alignment to correct the orientation of the face image into an upright frontal face image using affine transformation. The geometrical normalization is used to crop the upright frontal face image and scale it to a desired resolution. The cropped face image is used as the input image for face recognition.

D. Rotation:

The next step is image rotation. Since we are interested in some concrete face objects that can give particular information, we need all of them to be located in the same area for every image. Thus, we are able to make the feature extraction, obtaining the feature information from the same points, and the comparison between features from different images makes sense. The criterion for the rotation is to place both eyes in the same vertical coordinate (Y), as we assume that everybody has the eyes at the same height. Therefore, the eye position must be known. Once we know the eye position, we need to compute the rotation angle. The angle formed by the imaginary line joining the two eyes and the horizontal axis is computed (see Figure 3.4) with the formula

\[ \varphi = \arctan \frac{(\text{le}(y) - \text{re}(y))}{(\text{le}(x) - \text{re}(x))} \]

where, le refers to the left eye, re to the right one, and x and y the position of the horizontal and vertical axis respectively. Notice that using this technique, the angle changes from a negative value to a positive one when it is around 90 degrees because of the inverse of the tangent function. Thus, when the \( \varphi \) is bigger than 90 degrees the rotation is done in the wrong side, getting an upside down image. This is not a problem since, we assume that the angle will never be bigger than 90 degrees, which is not really a hard restriction because in the most of the applications that this system can have, all pictures will be taken in a horizontal way (with may be just a very little rotation).

Fig. 3.4: Rotation angle calculation.

When the angle is known, the image rotation is done with a Matlab function that has the image to rotate and the angle as input parameters, and as output the image rotated \( I=\text{imrotate}(I,\angle) \). Once the image is rotated, the
keypoints position also needs to be rotated. For doing so, the imrotate function is not useful, thus some transformation matrices have to be used. First of all we need to replace the axis in the centre of the image (Matlab places the axis in the upper-left corner), so the (0, 0) point will be in the middle instead of in the upper-left corner. It can be applied in order to obtain the position of the points in the new space, where $\phi$ is the same angle as found before. Finally, we need to replace the axis in the upper-left corner again with a matrix similar to M1 to avoid having negative values. For calculating the values of this matrix, we also need to know where the corners of the original image have been placed after the transformation, hence we create a matrix with the position of the four corners and we apply the rotation $M1 \cdot Mrot$ to this matrix. Then, we just need to move the 0 value of the axis to the lowest value of the corners rotated. Therefore, we find the lowest value of the X-axis and Y-axis, and these values are utilized in the transformation matrix. To sum up, the rotation is done using the formula.

$$rot = (erx, ery, 1) = (ex, ey, 1) \cdot M1 \cdot Mrot \cdot M2$$  \hspace{1cm} (2)

where, $ex, ey$ are the known values of the position of one eye, and $erx, ery$ are the position rotated in horizontal and vertical direction respectively.

E. Crop:

It is frequently the case that the input image has more information than just the face, so the background and part of the body also appear in the image. Since we only use facial information, it is required that the image has to be fitted to the face to avoid extra information which affects the system performance. This is achieved by using an averaged face size, which is the relationship between the face size and some facial distances. These distances are computed with the equations

$$disteyes = \text{right\_eye(x)} - \text{left\_eye(x)}$$ \hspace{1cm} (3)

$$disteye\_mouth = \text{eye(y)} - \text{mouth(y)}$$ \hspace{1cm} (4)

$$midpointeyes = \text{left\_eye(x)} - \text{right\_eye(x)} + \text{right\_eye(x)}$$ \hspace{1cm} (5)

The crop boundaries are calculated with the following formulae

$$\text{lower\_boundary} = \text{eyes(y)} - \text{disteye\_mouth} \cdot 1.5$$ \hspace{1cm} (6)

$$\text{upper\_boundary} = \text{mouth(y)} + \text{disteye\_mouth} \cdot 0.7$$ \hspace{1cm} (7)

$$\text{right\_boundary} = \text{midpointeyes} - \text{disteyes} \cdot 1.3$$ \hspace{1cm} (8)

$$\text{left\_boundary} = \text{midpointeyes} + \text{disteyes} \cdot 1.3$$ \hspace{1cm} (9)

F. Resize:

The amount of features that returns some feature extraction functions depends on the number of pixels in the image (for example in Gradient or Hessian). Due to the fact that we need to extract the same amount of features from each input sample, all the images have to be resized to a fixed size. Like in crop, the image size is a concern point in the project development and thereby initial values are set up, and are adjusted to the ones that fit the best. The initial values are 256 pixels in height and 192 pixels in width. The resize is done with the Matlab function $\text{im} = \text{imresize(im,[256,192])}$ which allows as input the original image and the size of the new one, and returns as outputs the resized image. If required, instead of the new size, the input can be the relation between the required size and the original size; hence the aspect ratio will not be modified. Whether making the images bigger or smaller, altering the number of pixels means to have pixels in new positions and therefore their value needs to be estimated. Matlab function allows us different ways to interpolate the values of the new pixels and we used the bicubic interpolation (the default one), in which the output pixel value is a weighted average of pixels in the nearest 4-by-4 neighborhood

G. Normalization:

The purpose of the image preprocessing module is to reduce or eliminate some of the variations in face due to illumination. The image preprocessing is crucial as the robustness of a face recognition system greatly depends on it. By performing explicit normalization processes, system robustness against scaling, posture, facial expression and illumination is increased. The image preprocessing includes photometric normalization which removes the mean of the geometrically normalized image and scales the pixel values by their standard deviation,
estimated over the whole cropped image. The photometric normalization techniques applied are based on Histogram Equalization and Homomorphic Filtering.

1) **Histogram Equalization:**

Gray level transformation is an image processing system that looks at every input pixel gray level and generates a corresponding output gray level according to a fixed gray level map. Histogram Equalization is the most common histogram normalization or image-specific gray level transformation used for contrast enhancement with the objective to obtain a new enhanced image with a uniform histogram or to produce an image with equally distributed brightness levels over the whole brightness scale. Histogram equalization is usually achieved by equalizing the histogram of the image pixel gray-levels in the spatial domain so as to redistribute them uniformly. It is usually done on too dark or too bright images in order to enhance image quality and to improve face recognition performance. It modifies the dynamic range (contrast range) of the image and as a result, some important facial features become more apparent. Histogram Equalization arranges the grayscale values of the image by using the histogram information. Histogram, an array of 256 elements containing the counts or number of pixels of all gray levels, is applied by Histogram Equalization to generate a special gray level mapping suited for a particular image. The accumulated density function of the histogram for the processed image histogram would approximate a straight line. The redistribution of pixel brightness to approximate the uniform distribution improves the contrast of the image. The result of this process is that the histogram becomes approximately constant for all gray values. The steps for Histogram Equalization algorithm are depicted in Fig 3.5

![Histogram Equalization algorithm](image)

2) **Homomorphic Filtering:**

Homomorphic Filtering algorithm is similar to that of Horn's algorithm except the low spatial frequency illumination is separated from the high frequency reflectance by Fourier high-pass filtering. In general, a high-pass filter is used to separate and suppress low frequency components while still passing the high frequency components in the signal. If the two types of signal are additive then the actual signal is the sum of the two types of signals. However, in this illumination or reflection problem, low-frequency illumination is multiplied instead of being added to the high-frequency reflectance. To still use the usual high-pass filter, the logarithm operation is needed to convert the multiplication to addition. After the Homomorphic Filtering process, the processed illumination should be drastically reduced due to the high-pass filtering effect, while the reflectance, should still be very close to the original reflectance.
**Age Classification:**

This paper proposed a novel and effective age estimation using face triangle from human face image as shown in Fig. 4.1. After detecting the face area, the eye area has been detected. The iris of the eye appears to be the darkest area. So, we detect right and left eyeball by searching from the eye area. After that mouth point has been detected from the face area. We can form a triangle called face triangle with three coordinate points left eyeball, mouth point, and right eyeball as shown in Fig. 1. The angle between right eyeball, mouth point, and left eyeball is called face angle. With age progression of a human the face angle changes. So, by calculating the face angle we can estimate the age group.

![Fig. 4.1: Face image with face triangle and face angle](image)

For estimating the age group the steps to be followed are as follows: (The implementation is done in MATLAB)

1. Identify a rectangular face area from given input face image.
2. From the face image, the eye region is identified.
3. The cropped image is then histogram equalized and is converted into binary image.
4. The binary image is divided horizontally into two parts. Upper part containing two eyes is denoted by UP and lower part containing mouth is denoted by LP.
5. UP is divided vertically into two parts. One part that contains right eye is denoted by RE and other part that contains left eye is denoted by LE.
6. The row number R1 with minimum row sum of gray level in UP is found. The column numbers C1 and C2 with minimum column sum of gray level in RE and LE are found. The (R1, C1) coordinate represents middle point of right eyeball and (R1, C2) coordinate represents middle point of left eyeball.
7. The row number R2 with minimum row sum of gray level in LP is found. R2 row represents the mouth row.
8. The midpoint C3 of two eye ball is calculated. C3= (C1 + C2) / 2 and the coordinate (R2, C3) is the middle point of mouth.
9. A triangle by three coordinate points left eyeball (R1, C1), right eyeball (R1, C2) & mouth point (R2, C3) is drawn.
10. Slope (m1) of triangle sides from mouth point (R2, C3) to right eyeball (R1, C1) and slope (m2) of triangle sides from mouth point (R2, C3) to left eyeball (R1, C2) are calculated.
11. The face angle (A) is calculated using formula: 
   \[ A = \tan^{-1}\left( \frac{(m1 - m2)}{1 + m1 \times m2} \right) \]
12. The age group based on the face angle (A) obtained is shown in Table 4.1

<table>
<thead>
<tr>
<th>Face angle in degrees (A)</th>
<th>Age group in years</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 44</td>
<td>&lt; 18</td>
</tr>
<tr>
<td>44 to 48</td>
<td>18 to 25</td>
</tr>
<tr>
<td>49 to 54</td>
<td>26 to 35</td>
</tr>
<tr>
<td>55 to 60</td>
<td>36 to 45</td>
</tr>
<tr>
<td>&gt; 60</td>
<td>&gt; 45</td>
</tr>
</tbody>
</table>

**Feature Extraction:**

Based on the age group classification the age can be narrowed. The appropriate features for the specific age group are considered. For the age group 1, the cranio facial growth is considered and for age group 2, the
horizontal and vertical distances are measured. For the age group 3, the texture is analyzed along with facial measures using gabor filters. For age group 4, the wrinkles are concentrated. For the age group 5, the skin texture especially, the cheeks and bridge of nose are considered to identify tanning, blemishes etc. The feature extraction is done using LBP and HOG(R-HOG) which are used for skin texture and skin wrinkles respectively. From these features the refined age can be estimated.

Age Estimation:
After the features are considered the age is estimated by using ANFIS method. The outputs of the classification are applied to ANFIS and the functions are derived. From these member functions, every image is assigned relatively an age from the stored results. The age can be computed by reducing the ambiguity of margin ages.

Conclusion:
Current face recognition technology has evolved to the point where its performance allows for its deployment in a wide variety of applications. These applications typically ensure controlled conditions for the acquisition of facial images and, hence, minimize the variability in the appearance of different (facial) images of a given subject. Commonly controlled external factors in the image capturing process include ambient illumination, camera distance, pose and facial expression, etc. In this paper, a method for estimating age group is analysed. The proposed technique provides a robust method for classifying the age group of the subject from the given scene image. For eye detection and eye ball detection, the face in the image should be without spectacles. Based on classified age group, the group specific features are extracted and are used for age estimation. This reduces the computation load on the system and requires less system resource, providing an efficient, robust and speedy automatic age estimation system which can be used in various applications from web cam based system to high end biometric accesses.

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