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Matching Facial Images using Age Related Morphing Changes

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***Abstract*—**Each year many people are reported missing in most of the countries in the world owing to various reasons. Arrangements have to be made to find these people after some time. So the investigating agencies are compelled to make out these people by using manpower. But in many cases, the investigations carried out to find out an absconding for a long time may not be successful. At a time like that it may be difficult to identify these people by examining their old photographs, because their facial appearance might have changed mainly due to the natural aging process. On some occasions in forensic medicine if a dead body is found, investigations should be held to make sure that this corpse belongs to the same person disappeared some time ago. With the passage of time the face of the person might have changed and there should be a mechanism to reveal the person's identity. In order to make this process easy, we must guess and decide as to how he will look like by now. To address this problem this paper presents a way of synthesizing a facial image with the aging effects.

***Keywords*—**Cranio-facial growth model, eigenfaces, eigenvectors, Face Anthropometry.

I. Introduction

HUMAN faces are subject to change mainly due to three reasons viz. age, gender and ethnic group. As the age seems to be the main cause of the facial changes, it has come to the forefront. That is because the changes of the facial appearance due to the aging show some unique characteristics when compared with other reasons. It is said that the face changes with age is hardly any news. It is found that the facial changes can happen within four periods of a human's lifetime. That is during the period of infancy, childhood, youth hood and old age.

According to the above mentioned periods of a human being, the facial growth happens according to the cranium of a person in the infancy period and the childhood. Therefore the researchers use a method called cranio-facial growth model [1] when synthesizing a face of a child whose age is between 1 to 18 years. And when it comes to the adults whose age is normally beyond 30, the synthesizing process is done by adding the wrinkle information to the facial images and by warping the facial features according to the age.

Each year many people are reported missing in most of the countries in the world. A man might disappear owing to some natural disaster, some mental problem such as dementia or perhaps he may be absconding in fear of punishment after committing a crime. In addition to these kinds of things there may be abduction of children and young adults. Arrangements have to be made to find these people after some time. Each year investigating agencies are compelled to make out these people by using manpower. But in many cases, the investigations carried out to find out an absconder for a long time may not be successful. At a time like that it may be difficult to identify these people by examining their old photographs, because their facial appearance might have changed mainly due to the natural aging process.

On some occasions in forensic medicine if a dead body is found, investigations should be held to make sure that this corpse belongs to the same person disappeared some time ago. With the passage of time the face of the person might have changed and there should be a mechanism to reveal the person's identity. In order to make this process easy, we must guess and decide as to how he will look like by now.

The main goal of this research is to find out whether a conclusion can be arrived at as to how the appearance of a face changes subject to age levels.

To achieve this goal, some objectives must be accomplished. One is to identify the facial features which are changing subject to time according to the gender and the ethnic group. That is because the facial changes subject to age depend on the other two reasons as well. Next one is to generate a photograph to suit the present age of a person by using his old photograph and then by distorting the features of that photograph according to the age and changing the skin tone of the facial image.

After generating the photograph for a particular person to suit his present age, that photograph will be matched with a set of photographs to reveal the identity of that person.

This research will be helpful in several face recognition systems such as prediction of the current facial appearance of wanted/missing people and to update the face images databases of the wanted people, and in forensic applications.

The rest of the paper is structured as follows. First, a brief literature review on the related work in this area is presented. Then the system design and the implementation of this research are outlined. Next the simulations of the aged faces according to the process suggested by us are depicted in the test results section. Then the evaluation part of the research is described and finally the paper will be winded up with the conclusion.

II. Related work

When it comes to the area of Computer Vision, the age progression in human face is dealt with two perspectives. First one is the automatic age estimation of a given photograph and the second one is the automatic age progression in a given photograph. When we manifest the aging effects on the facial

images there are two points to be considered, they are the shape and the texture of the facial images. Those are the two main things subject to variation across the age. Both biological and non-biological factors also have an effect in this connection.

Several researches have been conducted based on age estimation and the age progression.

Kwon et al. [2] have done age classification research and they have identified the facial features to find the initial rough oval, chin, sides of face, eyes, mouth, and nose and to compute the virtual top of the head. Then they have computed the facial feature ratios and computed the wrinkle analysis. To find out the above mentioned details they have used an energy equation which contains the geometric template for the face. These energy terms were related to potential fields that guide the template fitting process. The potential fields were formed from the image operations. After obtaining the geometric ratios they have added the wrinkles on the forehead, near the eyes and near the cheeks which were found by the snakelets. And that is the way how the wrinkles on a facial image have been analyzed.

Ramanathan and Chellappa in [1] have conducted a research on modelling age progression in young faces whose ages come below 18 years. They have proposed a cranio-facial growth model for this purpose. Hence we can get an idea about the differentiation of the growth of a facial image of a child and an adult.

Geng et al. [3] have proposed an automatic age estimation method called AGES (Aging Pattern Subspace). And there, they have clearly mentioned about the facial anthropometry.

Schroeder et al. [4] have done a research on facial aging using warping mechanisms and there they have taken into consideration only the shape of the facial features. But they have not analyzed the texture variations of the skin of a facial image. To change the shape of the facial features they have used the RBF (Radial Basis Function) transformation.

Leta et al. [5] have done a research on measuring the aging parameters across the age and they have come up with an aging curve for all facial features. Several researches are based on this aging curve since this aging curve is fitted as a result of an attempt of a group of expertise in various research fields. Therefore this aging curve is believed to be a highly accurate one.

Schroeder et al. [6] have done a research on facial Aging using image warping techniques and in their work too, they have used the aging curve which is introduced by Leta et al. [5]. They have used 'Radial Basis Functions (RBF)'for warping. RBF is a 2D spatial transformation mapping function. By using the values obtained by the above mentioned Aging curve they have done their metamorphism. It should be mentioned here that their main assumption was that an image is a 2D object and a finite domain of a plane with a grey level (or color) associated with each point. Therefore the warping process of an image is depicted as a transformation of the plane itself, and the grey level values are transformed according to the transformation of their associated coordinates. They have only taken into consideration the distortion of the aging parameters however they have not bothered about the wrinkle information.

There are several mechanisms that can be used in image warping and some of them are forward warping, inverse warping, mesh warping and field warping. Beier and Neely in [4] have introduced a warping algorithm called feature based warping which can be divided into two mechanisms: single line pair warping and multiple line pair warping. In multiple line pair warping, the pixels between two lines can be transformed into the gap between another two given lines. So this is the best warping mechanism that can be applied for this research because here, a given feature is going to be transformed along with the aging details to change that feature according to the age.

Joy et al. [7] have done a research on Anthropometric Study of the Facial and Nasal Length of Adult Igbo Ethnic Group in Nigeria. And they have taken into consideration the mean lengths of the face and nose and they have come to some conclusions based on their results. By doing this research they have shown that we can derive mean heights for the facial features based on the age gaps. By analyzing their results, it can be said that the height and width differences of the facial features based on the age gaps can be obtained. Moreover it can be said that by using these values the height or the width of a given feature can be changed with the aid of these mean values.

Many of the researchers have faced the problem of the data scarcity in training the aging systems. But now there is an aging database called FGNET database and it consists of 1002 photographs of 82 individuals and this database helps to overcome this difficulty to up a certain extent.

Up to now the paper has described how the aging functions and models work; now we will move onto the face recognition process.

Face recognition is identified as a very complex form of pattern recognition. In this process, the main function that happens inside is the classification of highly ambiguous input signals with multi dimensions and then matching them with the known signals. For this kind of a classification a large number of training data sets is needed. The very first step in the face recognition process is representing the face by a matrix. Normally face recognition can be classified into two classes viz. feature based (Geometric) and template based (Photometric).

Dimitri in [8] has proposed an algorithm for face recognition using eigenfaces and there are many other techniques in face recognition area.

III. Methodology

The design phase comprises of two main sub-phases. First one is the age progression on human faces and the second is the face recognition part.

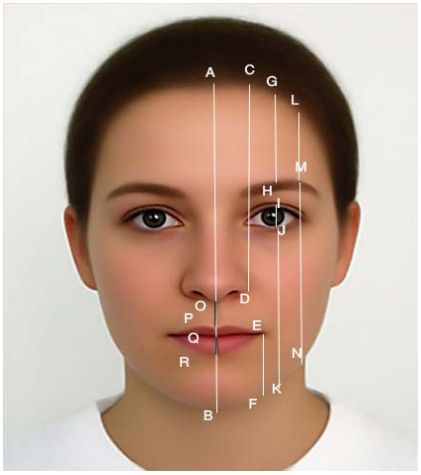
A.Age progression in human faces

This section is again divided into four steps, i.e., (a) calculating the distance differences of the facial features using face anthropometry, (b) warping the facial images using a

warping algorithm, (c) calculating the skin tone differentiation values across the age and (d) darkening of the texture of the facial image.

a) Calculation of the aging parameters

In this step, a set of images of American females whose age range is between year 20 and 50 are considered. Then 10 values based on the distances between some selected points of the facial image are found according to the face anthropometry shown in figure [1]. Then the differences of each distance for the age gaps are calculated to find the mean values for those distance differences.



Height of the face	→AB
The length of the cornea	→IJ
Elongation and rotation of the nose	→AO, CD
Ptosis of the central midfacial tissues	→OP
Width of the lips	→QR
Lateral pouches of the face	→RB, EF, JK, MN

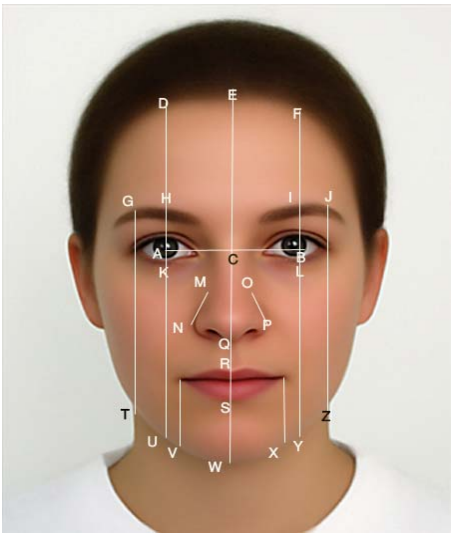
Fig. 1: Feature Points taken to the analysis

The steps followed in measuring those differences are described below. One of the main difficulties is the inability to adjust the pose of a person, because some of their poses cannot be taken directly into localizing the feature points as they are. So there should be a rotation of those kinds of photographs so that the two eyes are set horizontally.

The other major problem is the differences in the sizes of the facial images, since they vary according to the distance between the camera and the person posing for the photograph.

After that from each and every photograph in the sample images set, a sample data set is obtained by locating the feature points manually. So by taking into consideration only the 'y' values for the vertical lines as shown in the figure [2] which is shown the face anthropometry, some of the distances can be measured and the distances of the horizontal lines horizontal lines shown in the figure [2] can be measured by taking only the 'x' values.

Then for the age groups (20-25), (25-30), (30-35), (35-40), (40-45) and (45-50) the mean values for the above mentioned distance differences are calculated and then the new lengths for the facial features according to the ages are calculated.



Height of the forehead	→AD, CE, BF
Palpebral pouches	→AK, BL
Slough of the eyelids	→AH, BI
Elongation and rotation of the nose	→CQ, OM
Nasogenian fold	→MN, OP
Ptosis of the central midfacial tissues	→CR
Width of the lips	→RS
Lateral pouches of the face	→GT, AU, CW, BY, JZ

Fig. 2: Face anthropometry.

b) Warping the images

The feature based warping mechanism introduced by Beier and Neely [4] is used as the warping technique. Going into more details it can be said that this mechanism uses a technique called 'warping with multiple line pairs'. It uses a weighted combination of points defined by each pair of corresponding lines. Based on the features, a mesh is put onto the image to be warped. Then, the warped image can be obtained by distorting the mesh according to the new feature points.

c) Calculation of the skin tone differentiation values across the age

After transforming the facial features according to the ages, a change should happen in the skin color too. Because of the wrinkles, a person's skin tone would gradually become dark, when he/she grows old. In this process, the changing of the color is analyzed by using a set of photographs of females whose age range is from 20 to 50.

The procedure of taking the variation of the skin color is as described below. First, a set of images (7 images for age 20, 25, 30, 35, 40, 45 and 50) for each and every individual is taken to analyze the skin tones and the difference of the skin colors. The figure [3] shows a sample set of such images.

Fig. 3: A set of images from the sample data set.

In this phase only the gray scale images are used and then from the best illuminated parts from the images a sample with the same size is taken for the analysis. Before taking the skin samples, contrast stretching is applied as a preprocessing step on all images.

To study the texture variations in this section, the best way is to obtain the contrast values of each and every photograph. Contrast is the difference in visual properties that makes an object (or its representation in an image) distinguishable from other objects and the background. In visual perception of the real world, contrast is determined by the difference in the color and the brightness of the object and other objects within the same field of view. Since the human visual system is more sensitive to the contrast than absolute luminance, we can perceive the world similarly regardless of the huge changes in illumination over the day or from place to place. Here the RMS contrast has been used to study the texture variations of the images. In mathematics, the root mean square (abbreviated RMS or rms), also known as the quadratic mean, is a statistical measure of the magnitude of a varying quantity. This technique is highly used in measuring the current levels of the digital signals. Normally RMS values are used when the variants are in a shape of sinusoids (signals which have positive and negative values). When it comes to the image processing area, RMS value is used to measure the contrast. RMS contrast does not depend on the spatial frequency content or the spatial distribution of contrast in the image. And the RMS contrast is defined as the standard deviation of the pixel intensities.

The RMS (Root mean square) values for the pixels of the photographs can be obtained to estimate a color value for the selected area from each and every photograph. It should be made sure that all the texture images are in the same size so that we can have an accurate value as the answer. To have a set of texture images with the same size, all the images are resized into a pre defined size.

This process should be carried out with all the images for a particular person. And then by statistically analyzing all the values, the divergence of the color value from one particular age to another age can be represented by a graph. i.e., for the set of photographs of each and every individual, this process should be carried out to obtain a valid function. Then it makes the calculation easy, and there is no need to do complex calculations for each and every photograph as the pattern is known. Therefore, the calculation has been performed by studying the difference between two RMS values of two images.

In this research, a calculation similar to the aging parameters is carried out. i.e., the mean differences of the RMS values for the above mentioned age gaps are calculated and by using those RMS difference values the skin can be darkened by the following methodology.

d) Darkening of the texture of the facial image

In 'image darkening', first the given image is preprocessed, i.e., the image undergoes a contrast stretching process.

Then the given RGB image is converted to a gray scale image and then this algorithm compares each pixel with the adjacent pixels. It declares a threshold value for the color difference between the two adjacent pixels. If the difference is greater than the threshold value, it sets the color of that pixel to 0 (Black) and otherwise to 255(White).

After obtaining the edge detected image, the original RGB image and the edge detected image are added together by applying some mathematical operations on the pixels. Those mathematical operations are to adjust the colors of the facial images and the procedure of obtaining those values is mentioned in the previous section.

After adding the Edge detected image along with the original image, a texture is added to the above generated photograph. The texture used here is a texture of a skin and the methodology of adding these two images is described below.

First, the mean value for the texture image is calculated and then for each pixel, the pixel value deviation is calculated. Then the skin area of the facial image is detected and only for that area the deviation for each pixel is set to the deviation of the corresponding pixel of the texture. After that these two images are added together while changing the brightness of the texture according to the skin tone differentiation value and the age.

B.Face Recognition

This section describes about the face recognition phase let's take into consideration what is meant by the face recognition when it comes to this research. In the previous section we talked about a generation of an age simulated photograph and in this section we are going to recognize that generated facial image from a given set of photographs. This is carried out by following the eigenface concept. The main objective in this phase is to recognize the identity of a person accurately. Before going into face recognition, we should do something at the first level to train the system. Thus, the face recognition part is divided into two phases: the preprocessing of the images and the face recognition.

a) Pre processing of the Images set

The training process is described in this section. First of all a set of images should be obtained. For the naming convention let's say that there should be M number of images, and then those images should be transformed into a vector of size N to create the set.

In this process 25 images of the same age people are used in the file format of pgm. And then with the above taken similar set of photographs, a mean image should be obtained. Then the difference between the mean image and the input image should be obtained. Next a set of M orthonormal vectors

should be identified, which describes the distribution of the data. Then after obtaining the eigenvectors of the matrix, the eigenfaces can be obtained.

b) Face Recognition

Now the preprocessing phases are achieved, then the face recognition part should be implemented.

As the first step the input image should be transformed into the eigenface components. And then we should compare the input image with the mean image. Then the difference of these two images should be multiplied with each and every eigenvector of the matrix. Then the values obtained by this calculation should be assigned a weight and they should be stored in a vector. Then we would be able to determine the face which shows the best match for the given input image. In this, the minimum Euclidean distance should be calculated.

If there is a match between the input image and one of the stored images, the value of the Euclidean distance should be less than a pre defined threshold value.

According to this algorithm if the difference value is greater than the threshold and less than the second threshold value it implies that it is a face but an unknown face. When the difference is greater than the two threshold values it can be said that the input image is not a facial image.

IV. Results

To test this system, a set of images for a given facial image is generated for the six age levels and a comparison is carried out for those images with the actual images. Going into more details about the test data set it should be mentioned here that this set of images is from 20 people (who have got series of images for the 7 age groups (20, 25, 30, 35, 40, 45, and 50)) and each individual in the dataset has got at least five photographs of various age levels. Therefore, altogether there are 110 images in the test dataset. And then to test the system, the generated photographs are given to the system to recognize the aged person. The first evaluation is carried out by calculating the rate of correct identification of the generated photograph.

A generated 2 sets of photographs are shown below in figure [4]. Each of the photographs is generated with a five year gap and the first image is taken as a photograph at the age of 20 in the first series and 30 in the second series.

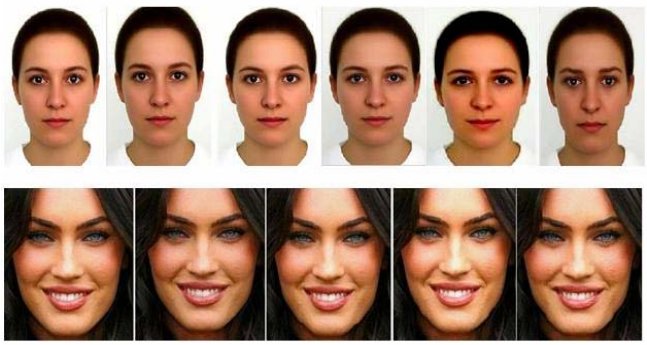


Fig. 4 Generated sequence of facial images.

Before testing the whole system to check the aging process, the aged photographs are compared with the original images. Each individual in the dataset has got at least five photographs of various age levels. In this phase for each individual a set of images for the other 6 age levels are generated and they are compared by mapping the faces.

After generating the aged photograph, they are given as the inputs for the images database and then the percentage of the similarity of the two photographs is checked. First, each and every generated photograph is tested with a set of the same aged photographs and then tested with a database which consists of all the photographs.

And by calculating correct identification rate, a conclusion can be arrived at, as this gives the perfect answer at a rate of 54%.

The screenshot of how the face recognition system works is shown in figure [5].

It should be mentioned here that for each given input image an output image is generated by the system with the average time of 6.448498 seconds. This time is calculated by giving 100 inputs to the system.

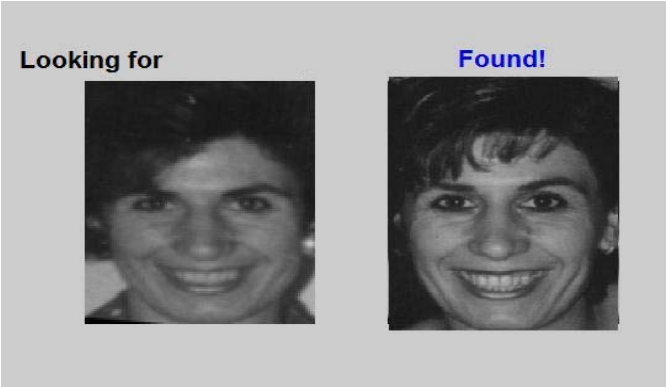


Fig. 5 Face Recognition output.

To test the skin color, the RMS values of the skin of the generated photograph and the original image should be compared. By doing this a conclusion can be drawn as this system gives the correct skin color at a rate of 49%.

V. Evaluation

An evaluation for a research is conducted to study the robustness of the findings. When it comes to this research the evaluation phase is carried out in two ways.

At first the system was tested with a test dataset which consists of 20 individuals' photographs and then the percentage of the accuracy of the system is calculated. And the way it has been carried out is described in the previous section.

In the second method a selected group of 25 people were allowed to use this system and then their comments were collected based on a questionnaire. Some of the persons were selected from the 4th year Computer Science batch at the University Of Colombo School Of Computing (who followed the subjects related to Image Processing) and some others were selected from the Faculty of Electrical Engineering at the

University of Moratuwa. They were allowed to give their inputs from the FGNET database which were not used in the test dataset.

In this phase, for each individual a set of images for the other 6 age levels are generated and they are compared by mapping the faces as mentioned earlier in the previous section.

And this is mainly evaluated based on a questionnaire.

By taking into consideration the feedback given by the people who used the system, a partial evaluation for the facial aging phase carried out is mentioned below.

Following the analysis of their opinion about the generated photographs, the quality of the photographs could be judged. They were allowed to give three inputs to the system and the output images were matched with the original photographs. After that they were allowed to give their opinion on the generated photograph.

The question is whether the generated photograph is similar to the original image and the sample users are allowed to give their opinion in four different categories as follows.

- Strongly agree
- Agree
- Disagree
- Strongly disagree

Out of the 25 people, 17 people gave their opinion as AGREE. And 8 people gave their answer as DISAGREE. But none of them gave their answers as strongly agree or strongly disagree. So it can be said that this system can satisfy the users' expectations at the rate of 68%.

And 19 people said (strongly) that the generated photograph does not look like an artificial one. And the answer of the rest of the sample agreed that this image does not look like an artificial image.

Based on the opinions obtained through the people who used this system, another evaluation for this part is carried out. The question is how to get the opinion of the user about the effectiveness of the face recognition system based on this phase.

By calculating the percentage of this, it can be concluded that this face recognition mechanism is not an effective method as there are 60% of negative feedback from the evaluators.

Out of the 25 people, 17 of them strongly declared that this system cannot be applied to the real world problems as it is, the other 8 also declared that this system cannot be applied to the real world problems as it is.

They suggested using a robust face recognition system which can analyze the faces feature wise.

By taking into consideration the responses of the selected evaluators, a conclusion can be drawn as the facial aging process is fulfilling the user requirements and this is capable of generating the aged photograph with an accuracy rate of 54%.

48% people said that the facial aging process is a highly user involvement process and it should be automated. But 49% people said that it is not a problem as this is an accuracy based system (and not a real time system). The people, who said, that this should be an automated system, gave the suggestion of selecting the feature points automatically.

These feature lines can be manually selected by using HAAR classifier or by using another technique. But if this automated system fails, the whole system will be in a mess.

According to the evaluation of this system, the face recognition system must be more robust than the eigenface based face recognition system. It is concluded that this should follow a feature wise analysis.

VI. Discussions

As we all know, the human faces are subject to change mainly due to age, gender and ethnic group. Among those things the age is the main cause of the facial changes. When compared with these three reasons, the changes of the facial appearance due to the aging show some unique characteristics.

It is found that the facial changes can happen within four periods of a man's lifetime. That is during the periods of infancy, childhood, youth hood and old age. In the periods of infancy and childhood, the facial growth happens due to their cranium. Therefore, the changes of the facial features are not enough to synthesize aged facial images in these periods. And in the periods of youth hood and old age, only the facial features are changing, but the cranium does not change. But after the age of 30, the wrinkles are appearing on the faces. Hence after 30 years, it is not enough to consider only the changes of the facial features. In addition to that the wrinkle information also has to be taken into consideration.

This research is conducted to synthesize the facial images of people whose age is beyond 30 years. This cannot be applied for the children as their faces grow according to the cranium.

The main goal of this research is to find out whether a conclusion can be arrived at as to how the appearance of a face changes due to the aging. So in order to accomplish this target, this research used an approach of calculating the mean distance differences of the identified facial features. In addition to that, the same methodology is applied to calculate the color variation of the skin due to the aging process. After all, the synthesized facial images are matched with a given set of images to recognize the person's identity.

By considering the rate of correct identifications of the generated image with the images of the database where they are stored to be matched with that image, and by considering the evaluation given by the above taken sample, it can be said that the synthesizing of an aged photograph is at a satisfactory level. That means the system has a capability of generating a photograph along with the aging details.

This research was conducted only for the American females, but this methodology which happens in a similar way can be applied to draw conclusions on the aging process in the facial images for each and every ethnic group based on the gender.

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