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A Robust and Novel Framework for Subdivision of Face Image Based on the Concept of Golden Rule

Nita M. Thakare[1], Dr. V.M. Thakare[2]
[1](*Department of Computer Technology, Priyadarshini College of Engg, Nagpur, India)*
[2](*Department of Comp. Science and Engg , S.G.B. University, Amravati, India)*

Abstract : *To implement any face recognition system, robust face representation and face image normalization is of vital importance. The performance of any face recognition system can greatly be affected by the poor performance of registration technique. 3D face recognition methodology has proved as most successful modality. This proposed approach is novel approach and used for subdividing the face into four face-stripes. This technique is based on leo-nardo-da-vinci's golden rule. The 3D face image is represented by modality which represents 2D information using depth map. To develop expression invariant face recognition system the face need to be subdivided into four regions so that the four major parts of face should be separated. The proposed approach had succeeded to present robust results, and insures improved performance of face recognition system.*
Keywords - *Face recognition, Normalization, Golden rule.*

I. INTRODUCTION

Depth maps are extensively used in 3D face recognitions; they represent the depth information of each point with respect to x-y plane. Thus it is the matrix containing z values on face model. The Depth map images are also called as 2.5 D representation of 3D images. These images have several advantages over 2D intensity images and 3D meshes. Depth map images are robust to the illumination change, which causes a significant problem in face recognition using 2D intensity images. Also, 3D information from depth maps is much easier to utilize than from 3D meshes. The researchers have suggested it as face information representation for improving robustness of face recognition systems with respect to illumination variation. Several previous approaches for face recognition using depth map images are focused on the face recognition process. The proposed work will focus on the pre-processing module of the 3D face recognition which will normalize a face images and then the depth maps with frontal view will be subdivided in to four parts based on the golden rule.

In 3D face recognition problem two main issues may affect the recognition performance; if normalization is performed using typical 2D methodology, size information which is important for the recognition process will not be achieved and if normalization is not performed then alignment of facial points necessary for good generalization will not be accomplished. Accurate and generic representation of facial data is of vital importance for robust performance of any face recognition systems. We address these fundamental issues with a 3D approach which uses depth maps for face recognition. The presented approach is carried out in two phases; Phase one enables a good alignment of 3D points across faces while still preserving face size information important for the recognition process. This is achieved using an average face model that can be scaled in 3D to best fit an input face. By scaling the model, opposed to the input face, proper size information of the face of interest can be encoded and better alignment of that face to the reference can be performed. An average face is the basis for a new coordinate system that provides a reference positions for rotating the faces and transform to the frontal pose. Input face to frontal face alignment is achieved using the Iterative Closest Point (ICP) algorithm. During the second phase the properly aligned and normalized depth map of 3D face is subdivided into four parts. This subdivision is based on the Leo-Nar do-Da-Vinci's golden rule of natural structures. [1][2]. Dr. Stephen Marquardt, a facial surgeon, developed a beauty mask based on the Divine Proportion The beauty mask is developed for males and females based on the Divine Proportion regardless of race, age, or nationalities. The concept of divine proportion for human face is based on golden factor, i.e. Phi which specifies certain proportion of human face structure. In the proposed approach the generic face image is successfully subdivided and the four main parts of the face; forehead, nose, eyes, nose and mouth are efficiently separated. The demonstration was carried out on two 3D face databases; CASIA and GAVADB. The Results have shown both good normalization and robust separation of face parts.

This Paper is organized as follows: Section 1 contains the introduction to the topic, in section 2 the work related to face part based face recognition and the approaches for subdividing a face image are reviewed. In section 3 the face image normalization technique is discussed. The images used for subdivision process are in 2.5 D format, Section 4 of this paper contains the process of depth map generation. Section 5 contains the explanation of the proposed approach for face subdivision. In this section the method for splitting the face image into four parts is discussed in detail.. Section 6 presents the experimental results and lastly section 7 concludes the paper.

II. RELATED WORK

Face recognition has a wide number of applications such as security, entertainment, and communication. The two dimensional face recognition systems encounter problems due to variations in pose, illumination and expressions. The researchers have found that 3D face recognition systems outperform the 2D face recognition systems because of their capability to represent the data in numerous ways as per the requirement of the system to be implemented. This paper presents a novel and robust framework to subdivide ace image into four major parts. This approach will be helpful to the researcher who is willing to develop the component-based or face part-based recognition system. The researchers have been working widely on component-based recognition separate descriptors using face parts (eyes, nose, mouth and chin), and the full face. And it has been proved that the most prominent face parts can complement each other in recognizing genders. In [5], the differentiation capabilities of full face, jaw, lip, nose, and eyes were evaluated by linear discriminant analysis. The most discriminant parts were the full face and jaw whereas nose and eyes have shown the poorest recognition capability.

In [6] the component-based system for face detection using SVM classifiers was proposed. The face detection was implemented by means of a two level hierarchy of classifiers. On the first level, the component classifiers independently detect parts of the face. On the second level, the geometrical configuration classifier combines the results of the component classifiers and performs the final detection step. Experiments on real face images show a significant improvement in the classification performance compared to a whole face detection system. In another paper [7] the authors have presented a component-based method and two global methods for face recognition and evaluated them with respect to robustness against pose changes. In the component system they have first located facial components, extracted them, and combined them into a single feature vector which was classified by a support vector machine (SVM). And it was concluded that the component system clearly outperforms both global systems. Weyrauch et al. [8] propose a component-based face recognition method using 3D morphable models for pose and illumination invariant face recognition. 3D morphable model is used to compute 3D face models from three input images in database. The 3D models are rendered under varying pose and illumination conditions to build a large set of synthetic images. Then, the component-based face recognizer is trained using these images. A component-based face detector is used to detect the face and extract components from the face. This system is much robust than the holistic face recognition system. Timo Ahonen et al. [9] extract the LBP texture features from each face region to form a enhanced facial feature vector. A classifier is built from LBP histogram features for each region. Weights are obtained manually to fuse the part-based classifiers. In our previous approach [10] the work was hybrid; for image representation the combination of geometrical and statistical methodology is used. Considering the discriminant capability of face parts , The prominent face parts are extracted using the grids and dimensionality is reduced using PCA algorithm. Based on the same concept a part-based face recognition method for near infrared (NIR) is presented in [11] in which a face is decomposed into several facial parts, such as eyes, nose, mouth, and their combinations, according to the analysis result. Then a part classifier is built for each part using boosted SLBPH features, and the outputs of part classifiers are fused to give the final score.

III. IMAGE NORMALIZATION

To cope with the problem of geometric misalignment image normalization must be accomplished. The process of normalization includes cropping of face image using mask to remove areas like neck and hair. Once the face region is extracted, the rotation transformation is applied to translate nose tip at the center of the bounding box.

For measuring similarity between the input face image and the images in database Iterative Closest Point (ICP) algorithm is used. This technique is extensively used for geometric alignment of three-dimensional models. The three steps of this algorithm are given as follows:

1. Locate the closest point as correspondence from the second face image for each point in the first face image.
2. The Transformation [R,T] is computed by minimizing the distance between the closest points .
3. This process is iterated until convergence to a local minimum.

For size normalization we first remove the unnecessary part of face like neck from face images. For this purpose we apply a threshold to remove area with less depth values. To determine the threshold value we have considered the depth values .The threshold value is decided by minimizing intra-class variances. When the threshold value is calculated, it is used to remove unnecessary part of the face images. The oval shape mask is used to crop the face region to bring all the images the same size. The threshold image is shown in figure 1.

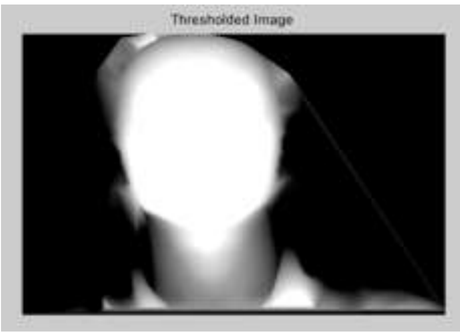

Figure 1. Threshold-image

IV. DEPTH MAP FOR IMAGE REPRESENTATION

The Some approaches reduce the 3D shapes to 2D to be able to apply well-known 2D operators. Depth map image [15][18] construction is a technique that follows this idea. In depth map images, the z coordinate of a vertex is considered to be the intensity in the corresponding 2D image. Each pixel's intensity is computed by either the vertex's z coordinate or by interpolation.

Thus 3D information is represented in the form of depth map. The depth maps are used as 2D representation of 3D image, containing the depth information of each point in the 3D image. It is simply an image with depth information as shown in Fig. 1-b. In other words, a depth map is an array of numbers where the numbers quantify the distances from the focal plane of the sensor to the surfaces of objects within the field of view. The closest point has the highest value. And therefore the closest point appears as white and farthest point appears as black giving the gray level values to the between points. The depth images have some advantages over 3D images [12]. The most important one is that the depth maps are robust to the change of illumination and color because the value on each point represents the depth value which does not depend on illumination or color.

The 3D face images contain highly accurate data but it is not feasible to process the large amount of facial data. Because the face model of each subject model has different vertices. The processing of the large data results into the expensive computation.

Face recognition systems based on 3D facial depth information improves the accuracy and robustness. But have not been addressed thoroughly. Only a few works on the use of depth map have been reported. The fusion of depth map and texture map is used in [13] where Fisher face and FaceIt techniques are used and FaceIt method outperformed on fusion of depth and texture information. The fusion of depth map and curvature information is used in [14].

In [15] we have generated the depth maps from the available 3D face images containing depth information. The training data set contains the normalized depth maps of all the subjects which are selected as the candidates for training datasets. Since our main objective is to evaluate the results for handling the illumination variations, all frontal images with varying light are considered as the candidates for the face recognition.

Fig 1a. shows the normalized frontal image from the CASIA database and fig 1b shows the depth image generated from 3D frontal image.

Figure 1. a) 3D Face Image b) Depth map

The normalization process is carried out to generate the normalized depth image. In this proposed system the depth maps containing depth information are generated from the available 3D face images. The training data set contains the normalized depth maps of all the subjects which are selected as the candidates for training datasets. Since our main objective is to subdivide the frontal depth map image, depth map of frontal images are considered as the candidates for the face subdivision. Figure 2. a shows the depth map generated from frontal image Fig. 2.b shows the mask generated to crop the face area.

Figure 2. a) Depth map b) Mask c) Cropped face images CASIA & GAVADB

In fig. 2. C the correctly cropped images from both the databases CASIA and GAVADB are shown. It contains only face region, the non face regions; like hair and neck portion are removed. The image shown in fig 1.c. is used as final input image for subdivision module of the face normalization process. The extraction of four horizontal strips is based on the Leo Nardo da vinci's golden rule which describes the golden value based (PI) rule for divine proportion of natural structures.

V. FACE SUBDIVISION

The face subdivision is carried out on the basis of golden rule. According to this rule Divine Proportion is everywhere. It is found in living and non living dynamic entities. Entire human population is genetically encoded to develop toward the Divine Proportion. Since Divine Proportion applies to every human individual, then there is a universal standard for facial beauty based on balance and harmony. Dr. Jefferson believes [1] that there is a universal standard for facial beauty regardless of race, age, sex, etc. All beautiful faces regardless of race, age, sex, and other variables conform to the Divine Proportion. Our face subdivision task is based on this concept. As shown in fig. 3, the vertical proportion is used to divide the face image into four major parts.

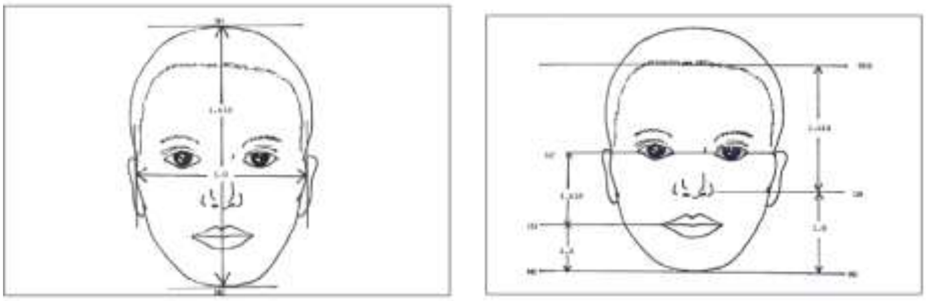

Figure 3. 3a. Proportion for face size 3b. Vertical proportion

According to Dr. Jefferson, Ideal height and width of a face is represented by the proportion as, if the distance between the two cheeks are 1, then the ideal height is 1.618 (fig. 3a) and Ideal vertical proportion is described as if the corner of the mouth (CH) to the bottom of the chin (ME) is one, then corner of the mouth to corner of the eye (LC) is 1.6183. If the corner of the nose (LN) to bottom of the chin is 1, then the corner of the nose to hairline is 1.6183 (Fig 3b). By considering the horizontal proportion as shown in figure 3a the face size is selected such that it would satisfy the proportion 1:1.618 . If we consider the proportion of chin, nose and hairline for subdivision of a face region, then to extract the four parts; forehead, eyes, nose and mouth the proportion 0.87, 0.43, 0.43, 0.87 respectively. Here as per the golden rule we have applied the proportion for the size of face also and to subdivide the face vertically the height of a face is roughly considered as multiples of 2.6 (1+1.6) which has resulted in to the proportion as 0.87,0.43,0.43,0.87. The successful subdivision based on this concept is shown in fig. 4.

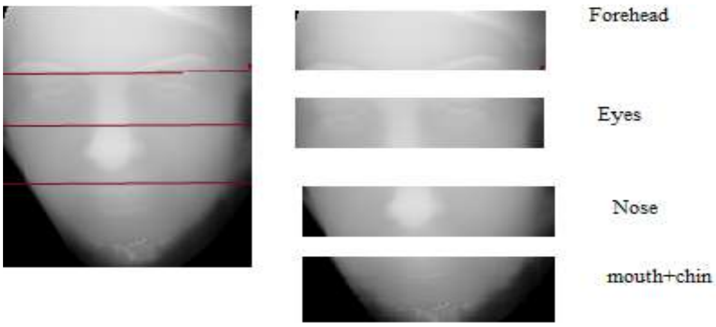

Figure 4. Subdivision of Face image

The golden rule for divine proportion describes the divine proportion for beautiful faces but here in the proposed face normalization techniques it has been observed that it is applicable all face which does not poses the abnormal face structure.

VI. EXPERIMENTS AND RESULTS

To test our proposed algorithm experiments are carried out on two 3D face databases; the CASIA database[17] and GAVADB database[18]. The CASIA database contains face images of 123 persons with 33 image samples per person. GAVADB contains the images of 61 individuals. For each individual 9 images are used to present variations in face poses and expressions. The experiments are carried out on these two databases to test the robustness of the subdivision method. In previous approach [16] the subdivision of face image was carried out to split the face image into three parts. The limitation of that approach was the use of only frontal images and the subdivision process carried out was not based on any benchmark or facial proportion.

The results in [16] have shown that the splitting up of face images outperforms the holistic approach but the subdivision process does not could not extract the salient feature of a human face instead it has divided the face into three even parts and does not considered actual facial features. In the proposed approach the input images with varied poses are taken. All face images are normalized according to the nose tip positions provided with the databases. The frontal face image is taken as training image. In this paper it has been found that the subdivision process is applicable to all face images except the images with large pose variation (more than 60^0) and experimental results (Table 1.) show that after pose normalization the result of subdivision has given better performance. For some images because of the improper masking and presence of a neck portion the system could not subdivide the face properly (Fig. 5). This results into the incorrect face subdivision, which in tern hampers the face recognition performance.

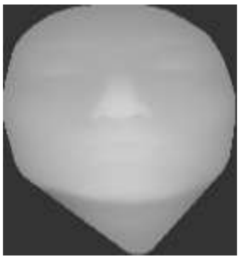

Figure 5. Incorrectly cropped face image

Expts.	No. of Persons		No. of images/ person	No. of images/ person	Input image	Subdivision performance		
	CASIA	GavaDB	Dataset 1 CASIA	Dataset2 GAVADB	Rotated/ Frontal	Correctly cropped	Incorrectly cropped	percentage
SET1	123	61	18	5	Frontal	2499	20	99.20
SET2	123	61	4	2	Rotated ($<30^0$)	609	6	99.18
SET3	123	61	4	2	Rotated ($<60^0$)	611	3	99.51

As shown in the Table 1. It has been observed that the use of divine vertical proportion of face image has resulted into the uniform performance; about 99% for both frontal as well as rotated images. Thus the pose variation of a face image does not affect the subdivision process and succeed in extraction of salient features like forehead, eyes, nose and mouth.

VII. CONCLUSION

In this paper, we demonstrate new framework to subdivide a face image into four parts showing the salient regions. The proposed method is fully automated, invariant to large rotation variation and robust enough for challenging face image. A simple and novel framework based on divine proportion concept is used for subdivision of face images and found that this framework is quite helpful in extracting the facial features . The face recognition methodologies using modular or component based approach will find this framework quite useful. The experiments conducted on challenging face databases demonstrate the effectiveness of our method.

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