3D Face Recognition from Complement Component Range Face Images

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***Abstract*— Face and facial attributes represent meaningful definition about a variety of information to discriminate an individual from others and for developing a computational model for automatic face recognition purpose. However, in this work, selection of relevant features from newly created face space is the pivotal contribution of the authors. Here, authors have demonstrated a new face space 'Complement Component' that have been used to extract the four basic components along X, and Y axes in four directions. Later, authors have experimented the discriminative attributes from these face spaces for recognition purpose. Here, comparison of the proposed method has been reported by examining its success on two well accepted 3D face databases, namely: Frav3D and Texas3D. In case of 2D face images, it does not contain depth like information i.e. Z-values in X-Y plane through intensity values. Therefore, it has not been undertaken during this investigation.**

Keywords—* *Face recognition; 3D face image; range face image; Complement Component;

I. INTRODUCTION

It is nevertheless to say that face recognition is superior to any other biometric measurements, such as heart beat rate, retina, hand geometry, DNA, signature, voice, etc. There are also certain reasons for such consideration, like: acquisition of human face image is non-intrusive in nature, it is easily available and most importantly face image has a major role in our social interaction. Although there are some advantages of available facial images, recognition of images under varying expressions, occlusion as well as pose bring some significant challenging issues to the researchers. At the primary level of this investigation, depth image has been decomposed into four basic components or 'Complement Components' along four coordinate planes to localize the most discriminative attribute for recognition purpose. It is the key advantage of the accomplishing the depth information in an X-Y plane instead of pixel data from the 2D image. The details of these mechanisms have been explained later in this paper.

Therefore, the main goal of this investigation can be characterized as:

- whether depth data (along Z-axis) itself carries any significant information?
- whether any underlying properties can be revealed from decomposed 'Complement Components'?

Hence, the main contribution of the authors of this research work is the creation of new face space 'Complement Component' using mathematical formulation that are having exactly the complements of each component along X, and Y axes either in positive or negative directions.

The remainder of the paper has been organized as follows. Section 2 provides a literature review on this topic. In Section 3, Complement Component has been detailed. Section 4 describes the proposed algorithm. The experimental result has been discussed in section 5. Section 6 provides the conclusion and future scope.

II. LITERATURE REVIEW

The proposed technique for designing new face space is new of its kind, authors have briefly introduced the most similar approaches from the current years. In [1], Wiskott et al. proposed component like mechanisms to localize and recognize faces using elastic bunch graph approach. Their technique is adaptive in nature. For feature extraction purpose Gabor wavelet coefficients have processed. Huang [2] et al., proposed fixed size, but a bunch of blocks to extract five face regions. These regions have been normalized and constrained characteristic based mechanism is followed to extract the components from where the pixel data have been utilized to extract feature. Zhang [3] et al. also proposed a new component extraction mechanism with a fixed size of windows which have been overlapped with each other from the normalized face image. Later, it has been divided into four sub-sections to accumulate the pixel data from each component for feature extraction purpose. All these experiments that have already been discussed here are mainly applied on 2D visual images. Also, some component based feature extraction approaches have also been carried out on the infrared face images. Heisele [4], proposed an approach where different components are used to extract the reference points from 3D morphable face model. Moreover, Spreeuwers [5], claimed a new 3D face recognition mechanism using region classifier where various face regions have been extracted from thirty regions like template or components.

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With comparison to literature review on extraction of various facial components, significant improvements have been proposed in the present method. These are described below:

- The new component extraction technique is independent of any particular template.
- Like conventional methods, no fixed size of the window or block for extraction of components have been considered.
- The extraction of components would be applied to frontal, rotated as well as occluded range faces images.

III. COMPLEMENT COMPONENT

The component-based face recognition mechanism could be categorized either into feature based methods or holistic method. Here, authors have considered feature based face recognition technique from newly discovered Complement Components. There are numerous approaches exist to extract facial components that are already detailed in section 2. Among them, 'Complement Component' reported in this research article is new for extracting different face regions by accomplishing depth information in four directions in X-Y plane from the 3D image. Particularly, the range images used to preserve depth data that have been processed along two axes in four directions to extract the four basic face regions from X-Y plane. These four directions are $X > 0, Y > 0, X < 0$ and $Y < 0$ in the X-Y plane. The depth information from range image can be interpreted by equation 1.

$$Z = f(X,Y) \tag{1}$$

where Z denotes the depth data of X-Y plane.

To obtain the depth values along these four directions, authors have followed the equations 2 to 5. In fig. 1, extracted four basic Complement Components from a single range face image along four directions have been depicted.

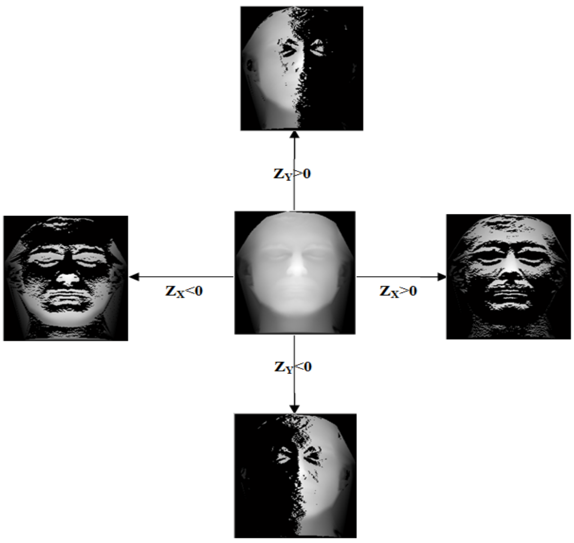

Fig. 1. Four basic Complement Components along four coordinate directions from range face image.

$$Z_X = \frac{\partial f}{\partial X} \tag{2}$$

$$Z_Y = \frac{\partial f}{\partial Y} \tag{3}$$

$$CC_{X>0} = if\ Z_X > 0\ and\ CC_{X<0} = if\ Z_X < 0 \tag{4}$$

$$CC_{Y>0} = if\ Z_Y > 0\ and\ CC_{Y<0} = if\ Z_Y < 0 \tag{5}$$

In these equations Z_X, Z_Y are the first order partial derivative along X and Y axes respectively and $CC_{X>0}$, $CC_{X<0}$, $CC_{Y>0}$, $CC_{Y<0}$ are the four basic Complement Components. Again, due to the computation of derivation on discrete data points rather than continuous plane, partial derivatives have been considered. However, as the investigation is focused only to extract four components along four directions, authors have not considered some points where $Z_X = 0$ and $Z_Y = 0$. Here, authors have calculated that approximately average of 1.91% and 2.15% negligible data points from range face images of Frab3D and Texas3D databases have been discarded.

Again, for naming convention, Complement Component, authors have followed qualitative as well as quantitative analysis. For the qualitative analysis, subjective fidelity criterion is followed by eight volunteers whereas, equations 4 and 5 have been considered for quantitative measurement. Among eight volunteers, all of them have acknowledged that these facial components are complements to each other along any axes (either along X axis or Y axis) and equations 4 and 5 also justify this.

Moreover, there are certain advantages of this newly derived face space, Complement Component, that have been summarized below:

1. Due to accomplishing the depth values rather than pixels intensity value, this method explicitly describes more detail information from range face image than corresponding 2D images.
2. Extraction of facial components are independent of expression, pose, illumination as well as occlusion.
3. Mathematical formulations follow this technique. Neither empirical nor heuristic approach is accomplished by considering the block sizes of components.
4. It would be significant to extract the face regions in the presence of occlusion. During classical approaches, extraction of components from occluded faces might contain only occluded portion that leads to poor recognition performance.
5. Furthermore, individual components from Complement Component face space could be considered for further investigation.

IV. PROPOSED METHOD

The proposed method consists of different sub-processes that have been discussed here. In fig. 2, a block diagram of the proposed method is presented. It consists of 3D image acquisition i.e. accomplishing of 3D face image databases, creation of 2.5D range face image, accomplishing Complement Component, feature extraction, and classification.

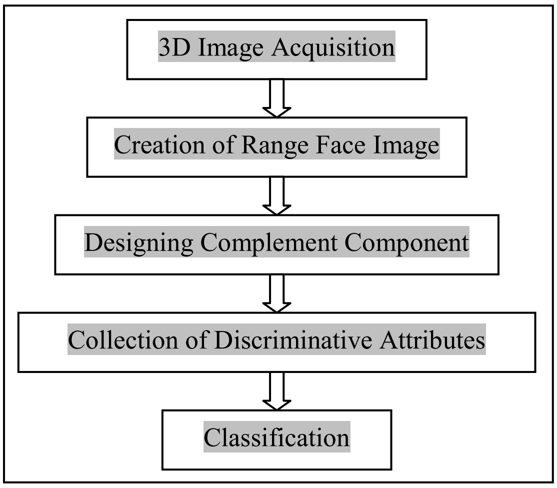

Fig. 2. Block diagram of the proposed method

Now, as because the main focus of the proposed method is to introduction of new range face image space, Complement Component, and its implication for range image based 3D face recognition, authors have briefly detailed the preliminary attributes of the proposed method.

A. 3D Face Image Databases

It is already known that 3D images are consists of three data points across three axes rather than conventional intensity values from 2D images. Now among two considered databases, Frav3D database [7] consists of 3D face images whereas Texas3D database [8] contains only range images. Again, for implementing the proposed new face space, it is very much required to have depth data (Z's value) in the X-Y plane.

To propose the credibility of the proposed mechanism, authors have manually computed an X-Y plane for the range images of Texas3D database. Furthermore, the same has been tested for corresponding 2D face images of the databases. However, to the lack of depth like detail information, extraction of Complement Component fails for conventional 2D images.

Moreover, Frav3D database consists of possibly all types of face recognition challenges, such as pose, expression, illumination, whereas Texas3D database contains only frontal range face images with varying illumination.

B. Creation of Range Face Image

Range face image is also termed as 2.5D image [6] or depth image. As because of depth data, the Z's value, are used to create range face images, it is also known as depth image. Again, 2.5 dimensionalities is used to highlight the importance of depth data of 3D image over conventional 2D image's pixel information. In [6], Ganguly et al. proposed the algorithm to create the range image that have been followed here.

C. Feature Extraction and Classification

The computation of whole range face image for recognition purpose requires the discriminative attributes that could represent the individual images accurately. In this investigation also, authors have followed same basic principle. Authors have applied SVD [9] to extract features from Complement Component for estimating the most discriminative attributes for recognition purpose.

Although PCA and SVD are eigenvalue methods, SVD [10] is chosen for its simplicity and correctness. The components have also been resized into a fixed size of 234×194 using bicubic interpolation technique [11]. Now, from this difined size of Complement Component range face images 194 non-zero eigenvalues have been obtained as the features to discriminate the individuals. These non-zero values are the square-root of the eigenvalues. Although the selection of such image dimension is empirical, the proposed method is capable of processing any random image size. During training and testing, the images that are not in the specified size, have been resized by bicubic interpolation technique.

Therefore, for each component 194 feature attributes have been estimated. Hence, from four components total 776 (194×4) features have been determined from single range image to discriminate it from others for recognition purpose. The individual feature set from each component has been combined linearly to create the final feature vector from each range face images.

Later, the feature vector have been transferred to the classification module. Here, it will be classified by SVM classifier [12-13]. From the feature pool, the feature vector is arranged in a 2D matrix form where row numbers indicate class numbers and columns number define number of features. Now, from this feature vector single fold cross validation mechanism has been followed during this investigation. Additionally, four different kernel functions, such as Radial basis, Polynomial, Linear, and Sigmoid, have also been accomplished by SVM classifier to carry out the classification task and measure the accuracy.

V. EXPERIMENTAL RESULT AND DISCUSSION

To establish the robustness of the proposed method, the proposed method have been validated on frontal as well as overall range face images. Therefore, a side-by-side comparison of recognition rate has been done between frontal range images from Frav3D as well as Texas3D databases. Moreover, success rate from overall available range face images that are invariant to pose, expression, illumination, from Frav3D database has also been observed. In Table 1, authors have presented these results.

TABLE I. RECOGNITION RATE FROM LINEAR COMBINATION OF FEATURE VECTORS

SVM Kernel Functions	# Features	Frontal dataset	Overall dataset
Frav3D Database			
Radial basis	776	94.80%	91.28%
Polynomial		***95.87%***	92.08%
Linear		93.19%	91.78%
Sigmoid		94.32%	***92.3%***
Texas3D Database			
Radial basis	776	97.13%	NA
Polynomial		96.69%	
Linear		***96.89%***	
Sigmoid		96.69%	

From the analysis of the recognition rates from Table 1, it has been observed that there is a variance of 0.7938 between the recognition rates of frontal range face images from two databases. Furthermore, it has further been noticed that the proposed method could also recognize the un-normalized range face images that are invariant to pose, expression, and illumination.

In comparison with the method discussed by Hajati et al. [14], Ganguly et al. [15], the proposed method performs well. In these methods, authors have either followed curvature based local surface information [15] or geodesic distance [14] based global facial details for recognition purpose. However, in the proposed method the novelty is to extract four new components along four directions of range face image to discriminate the individuals from 3D images.

VI. Conclusion and Future Scope

This paper has conducted a study on the extraction of facial components based on depth value i.e. values along Z-axes with respect to X-axis and Y-axis. Again, these extracted components have been named 'Complement Component' from qualitative as well as quantitative analysis. During this investigation phase, authors have also carried out an exhaustive experiment on two databases. Meanwhile, authors will also investigate the effect of these Complement Component face images for recognition purpose in more robust and unconstrained environment.

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