3D Face Reconstruction by Pose Correction, Patch Cloning and Texture Wrapping

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Abstract— **Face is being considered as one of the most commonly used biometric modality. The inaccuracy in two dimensional face recognition systems is mainly due to pose variations, occlusions, illumination etc. Among this, changes in illumination condition do not affect 3D face recognition systems. But pose variation drastically changes the appearance of face images. To solve the problems with depth map and texture images corrupted by head pose variations and the occlusions generated due to these pose variations, a reconstruction method is proposed which consist of three stages. In the first stage, the pose correction is done by Iterative Closest Point (ICP) algorithm and in the second stage the occluded region of the face is reconstructed by a resurfacing method called patch cloning. It is followed by the wrapping of reconstructed depth map by its texture to generate a 3D model. The statistical error between the original face and the reconstructed face is also evaluated. In this work, facial symmetry is used as a prior knowledge. Experiments are done with the FRAV3D database.**

Index Terms— **Face recognition, Face Resurfacing, Pose Correction, ICP algorithm, Patch Cloning**

I. INTRODUCTION

Face recognition is widely used in many fields like computer vision, identity verification, criminal face recognition etc. A number of face recognition methods have been developed since 1960s [1]. However it is still a great challenge for face recognition in practical applications due to problems like illumination, occlusion, pose variations etc. Many of these challenges faced in 2D face recognition technology have been solved by 3D face recognition. One advantage of 3D face recognition is that it is not affected by changes in illumination conditions as 2D recognition methods. In order to solve the problems like occlusion, pose variation etc. in 3D face recognition systems, we have to go for face reconstruction.

Facial landmark detection is an important step in facial analysis for biometrics. Different types of facial feature fusion methods [6] were proposed by Panagiotis Perakis. They evaluated that the similarity fusion gives some good performance. Cesare Ciaccio introduced an approach for face recognition robust to head rotation. Face representation based on the combination of covariance descriptor and local binary pattern is introduced in [3]. There are some other works [4],[5] which exploits the facial symmetry as prior knowledge.

Gee-Sern (Jison) Hsu proposed a resurfacing method [2] to handle the quantization noise. Due to the large distance between face and the RGB-D camera, the depth maps are corrupted by quantisation noise. Here the resurfacing is done with the help of high resolution patches from another face. But in this case most of the failures are caused due to the difficulty to distinguish the resurfaced face since the resurfaced face loses some similarity to the actual face. So in this paper, we are introducing a reconstruction technique which reduces the failure rate and increases the recognition rate. Histogram of statistical error is also plotted.

The rest of the paper is organized as follows: The proposed work consists of three stages. First one is pose correction using the ICP algorithm followed by the face resurfacing using patch cloning. 3D model is generated at the third stage. Statistical error between the original face and the reconstructed face is also analyzed. An extensive experimental study on database namely FRAV3D is reported. Last section gives a conclusion to this study.

II. PROPOSED WORK

This method is related to the 3D reconstruction of facial images using the assumption that the face is symmetric in nature. It contributes a study of pose correction by ICP algorithm, face reconstruction using patch cloning method, generation of 3D model and characterization of statistical error. Block diagram of the proposed method is shown in Fig.1.

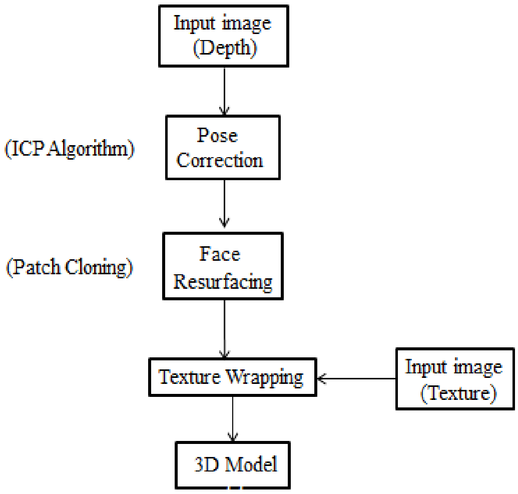


Fig. 1. Block diagram of proposed method

A. Pose Correction by ICP Algorithm

Here, the proposed work focusing on the challenge of 3D head pose variations and the occlusions due to those variations. The RGB-D cameras can capture face images with both the colour and depth information. The 3D pose variant images are created by rotating the frontal pose along the z-axis. The face image with pose variations and without right half is considered as the synthetic image. Pose correction is done with the help of Iterative Closest Point (ICP) algorithm. ICP is used to minimize the difference between the two point clouds. In the ICP algorithm, one point cloud, the reference, is kept fixed, while the other one is transformed to match the reference.

The steps in ICP algorithm are:

- For each point in the probe point cloud, find the closest point in the reference point cloud.
- Calculate the combination of rotation and translation using a mean squared error function
- This error function can be used for aligning the input point cloud to that of reference.
- Transform the points in the probe image using the obtained transformation.

After the pose correction using ICP, both reference and probe point clouds are converted in to depth maps. Then the occlusions in the depth images and point clouds are reconstructed using a resurfacing technique called patch cloning.

B. Face Resurfacing by Patch Cloning

This stage is required for the cases where the texture or depth image is deteriorated due occlusions. An approach to find the corrupted depth patches at specific local regions [9] is proposed. The approach replaces this depth patches by the corresponding depth patches from the symmetric part of the same face, and resurfaces the face in a best way. It consists of the following steps:

- Resize the depth map of test face with that of the reference image.
- Detect the facial region which is corrupted due to pose variations or occlusion. Correlation technique is used which gives the difference between the reference and the test images.
- Find the corresponding face regions from the symmetric part.
- Replace the corrupted depth patches by the fine layered depth patches taken from the symmetric part of the test face itself.

C. Texture Wrapping

In this stage the texture image is wrapped with the reconstructed depth map to obtain a 3D model. First of all a mesh grid along x-y axis is created. In order to wrap the texture and depth images, a 3D surface is generated with mesh grid along x-y axis and the resurfaced depth map along z axis. Resurfaced depth map and texture image were projected to this surface so as to obtain a 3D representation of the test face.

After reconstructing the 3D faces, the statistical error between reconstructed face and other faces is calculated. The same is done for the original face and other faces. These two error rates are plotted with the help of histogram so as to analyze the difference between the above two.

III. Experiments and Results

A multimodal database FRAV3D [7] is used for this method. It consists of texture information (2D image), depth map (2.5D image) and VRML file (3D image). The texture image is in the form of RGB image and depth map is in the form of point cloud. The database contains 100 persons and 16 samples per person with different head pose variations.

The frontal view of depth images is rotated along z-axis to create pose variation. The right half of the rotated image is removed as occlusion. The resultant synthetic image is further used for the reconstruction. An example of synthetic image is shown in Fig.2.

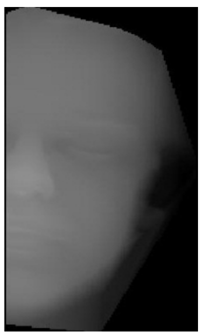


Fig. 2. Synthetic image

ICP algorithm is then applied to the point cloud of probe image with the frontal view as the reference point cloud. Fig.3. shows the side view of the pose corrected point cloud.

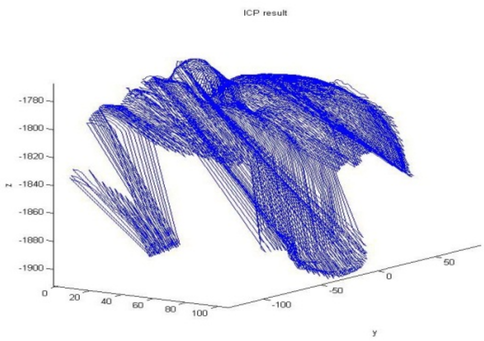


Fig. 3. Pose corrected point cloud

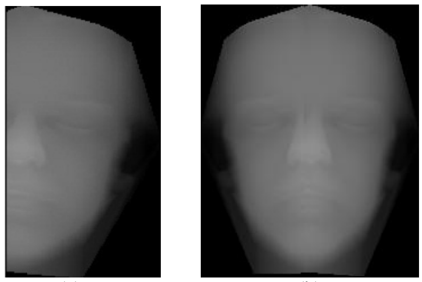
Now the point clouds are projected back to the depth maps. The right half of the face is created by concatenating the projected depth map with a matrix of zeros. This image is then used as the source image for correlation which is shown in Fig. 4.

Fig. 4. Source image for the correlation

After creating the source image for correlation, the difference between this source image and reference is calculated using correlation method. The correlated output is given in Fig.5.

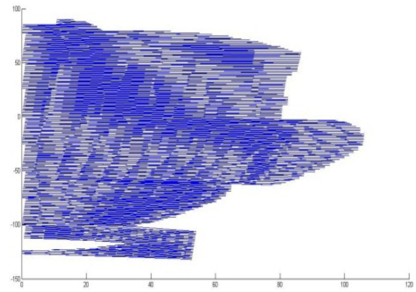
Fig. 5. Correlated output of depth map

From the output of correlation, the corrupted patches or parts of the face is calculated and these parts are replaced by the corresponding patches from the symmetric part of the same face itself by the resurfacing method called patch cloning. Fig.6. represents the depth map of actual face and the reconstructed face. Fig.7. shows the point cloud of actual face and Fig.8 gives the point cloud of reconstructed face in different views. The same procedure is repeated for the texture images also.

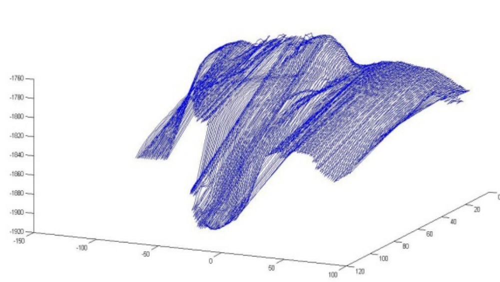


(a) (b)

Fig. 6. Depth map of (a) actual face (b) reconstructed face

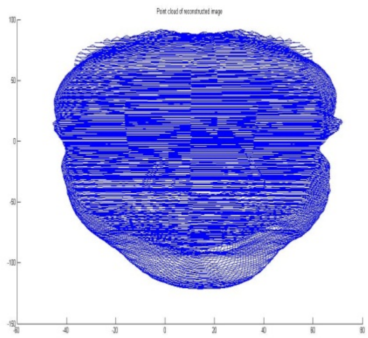


(a)

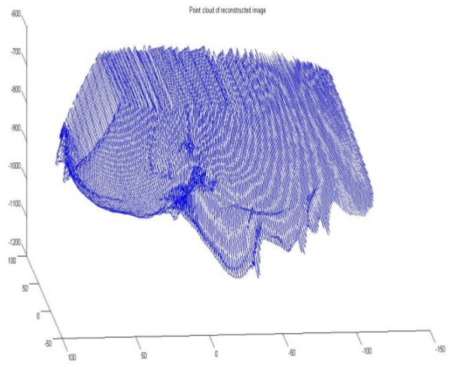


(b)

Fig. 7. Point cloud of actual face, (a) Frontal view, (b) side view



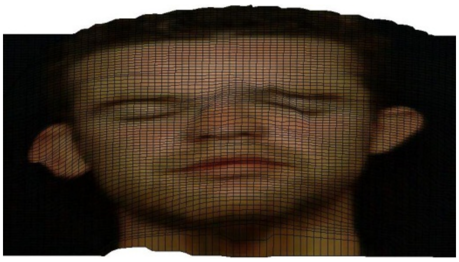
(a)



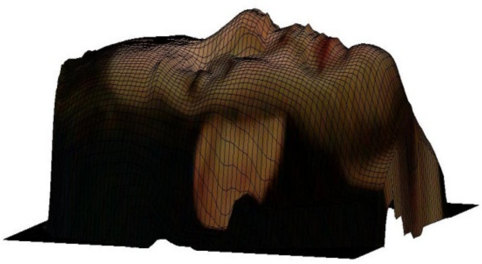
(b)

Fig. 8. Point cloud of reconstructed face, (a) frontal view, (b) side view

The 3D model is generated by wrapping the reconstructed depth map (Fig. 6(b)) with the texture image. The frontal and side view of the 3D model is shown in Fig.9.



(a)



(b)

Fig. 9. Texture Wrapped 3D model (a) frontal view, (b) side view

The error rate between original face and other faces is calculated. It is then compared with the error rate between the reconstructed face and other faces. The histogram plot which is used for the comparison of above two error rates is shown in Fig. 10. In this graph the dashed line represents the error rate between reconstructed face and other faces (ROT) whereas dotted line represents the error rate between original face and other faces (OOT). These two lines lie closer means the error between original face to reconstructed one is minimum. The solid line shows the error rate between the reconstructed face images with original one (OR) which lies closer to zero.

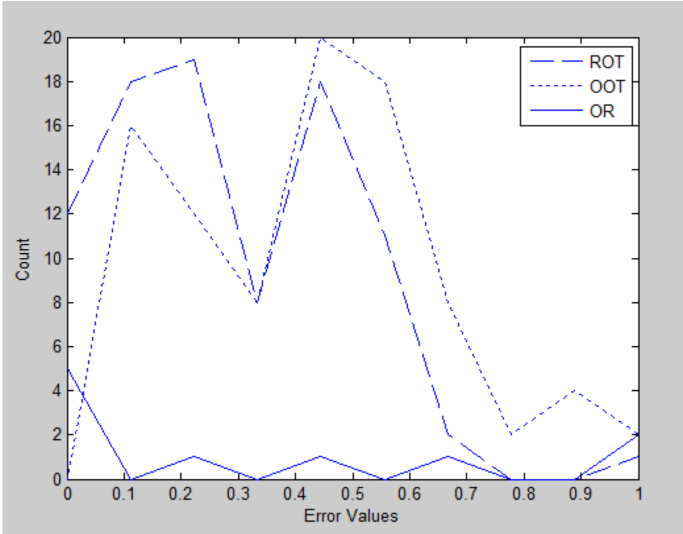


Fig. 10. Histogram of statistical error rates

A. *LBP Based Face Recognition*

The accuracy of the proposed reconstruction method is evaluated by LBP based face recognition [10]. Features from depth and texture are fused together for obtaining improved accuracy [8]. Recognition accuracy with and without reconstruction are compared in order to analyse the importance of reconstruction as a pre-processing stage in recognition systems. The comparison is given in Table 1.

TABLE I. ACCURACY WITH AND WITHOUT RECONSTRUCTION

No. of Samples	Accuracy without reconstruction	Accuracy with reconstruction
30	43.33	90.00
40	40.00	87.50
50	34.00	78.00
60	33.33	81.50
70	32.85	81.50
80	32.50	78.75
90	35.55	82.00
100	34.00	78.00

In [2] author claims that their reconstruction method for occlusions on the left profile, right profile and eye provide accuracies of 76%, 77% and 83% respectively. For 100 samples, our proposed reconstruction method gives an accuracy of 78% (Table.1).

IV. CONCLUSION

A resurfacing method to handle the occlusion problems in texture image and depth map is proposed. The pose variations are corrected by ICP algorithm and it is followed by the resurfacing method. Resurfacing technique using patch cloning can also be done using the patches from an another face. But in that cases the failure rates are higher. The proposed approach uses facial symmetry as the prior information and the patches from the same face is taken so as to minimise the failure rate and to increase the recognition rate. 3D model of the reconstructed depth map is generated by texture wrapping. The accuracy of this reconstructed method is evaluted using statistical error characterisation and LBP based face recognition.

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