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# Analysis of 3D Face Modeling

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***Abstract***

*This article presents the topic of Three Dimensional facial reconstruction approaches and some used methods. In this paper, we implement three-dimensional facial reconstruction algorithms based on various face databases using single image as an input and analyzing their performance on several aspects. Researchers proposed many applications for this issue, but most have their drawbacks and limitations. Secondly, we discuss about three-dimensional shapes and models based on facial techniques in detail. It concludes with an analysis of several implementations and with some technical discussions about 3D facial reconstruction.*

***Keywords:*** *Face modeling, Facial reconstruction, Cosmetic procedure, Face representation*

## 1. Introduction

Recently, many methods have been used to generate real three-dimensional facets from images. Advancement in 3D face processing has become more interesting and nowadays are being used in many security applications. 3D face modeling has currently been receiving a lot of attention among the computer vision and graphic communities and is a thriving research Field that can yield many applications such as virtual reality and animation. In addition, the reconstructed face needs to be compact and accurate, especially around significant areas, notably the nose, mouth, orbits and teeth *etc.* [1]. An extensive number of surveys for 3-D facial reconstruction in general already exist, [2-7]. In this paper, we will review the three-dimensional facial constructions on different databases and evaluate their performance. Secondly, we will discuss about the algorithms used for facial reconstruction. We will determine and quantify the most important factors that influence algorithm performances. This paper is structured as follows.

## 2. Three Dimensional Faces Based on USF Database

We provide experimental detail of USF databases. For this purpose, 77 faces were selected, including male and female with different ages and values. Laser lights were used to obtain the models containing depth and texture maps of real faces. Texture maps were used as an albedo, where it contains some considerable effects of lighting. Most probably some errors introduces to reconstruction. We used 3D face from the database as a reference according to Lambertian Law the YaleB database, which consists of different images with different conditions used as an input. The photometric stereo method was applied to evaluate the reconstructed images. Each photometric reconstructed face contains ten images and for rest of the experiment’s images were used from the internet and other sources. In the case when laser scans or photometric stereo reconstructions were available, the accuracy of algorithms are shown by error maps. The database calculated errors of 77 images over 19 different lighting. The graph represents the number of models that produce each value of error. The total mean and standard deviation of this error is 49.+1.2. The Azimuth and Elevation is a degree in Figure 2. Error reconstruction with 19 different lights, where color schemes from blue to red represents low to high. The implementation of the technique on MATLAB took 9 seconds on a quad-code AMD processor, Linux workstation 20 minutes takes on optical flow implementation. In Figure 1 the output of USF database involved in reconstruction process is shown.

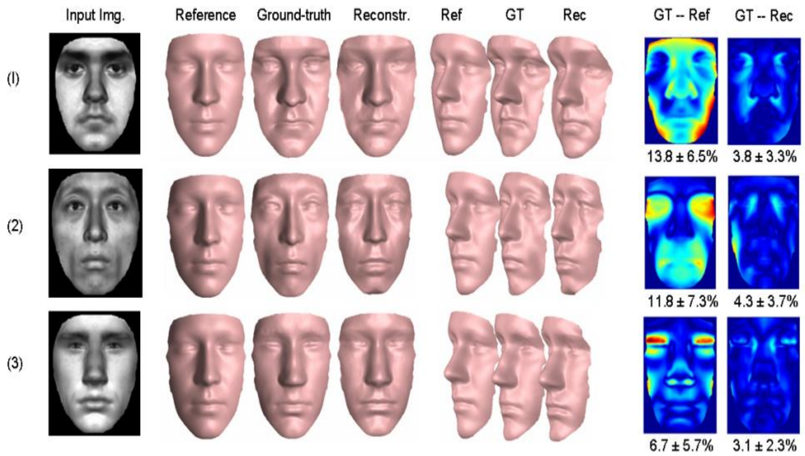


**Figure 1. [20] Experimental Results of 3D Reconstruction via USF Database**

Four examples are mentioned in figure, where from left to right input images and the three output images are shown, which were created using reference model, ground truth and laser scan.

## 3. Three Dimensional Face Shape Based on Anatomical Database

Image processing is considered an important tool for diagnosing and assessing diseases such as those of long-time smokers, searching for nodules (tumors) that indicate the presence of cancer *etc.* Human model anatomy also plays a significant role in therapy-related image processing. Anatomical knowledge is supposed to be an important area of medical and biological sciences. [8] Transmission computerized x-ray tomography (CT) supplies us the required high-resolution, three-dimensional human anatomy is necessary to construct the volume-segmented phantom [9]. Anatomical knowledge is divided into two categories: spatial and symbolic. Spatial anatomical knowledge presents geometrical attributes of biological objects such shape, size and three dimensional inter-relationships [10] The three-dimensional shape of humans is widely used in multiple applications, especially in online shopping, such as for glasses *etc.* In this section we apply three-dimensional face algorithms using anatomical databases. PCA, which stands for Principal Component Analysis, has been used to reduce the parameter estimation problem of eigenvalues. However, face shape obtained by using single shading images. Initially eigenvalues obtained from databases by applying PCA:

$$T = T + Pn \cdot An \tag{1}$$

 

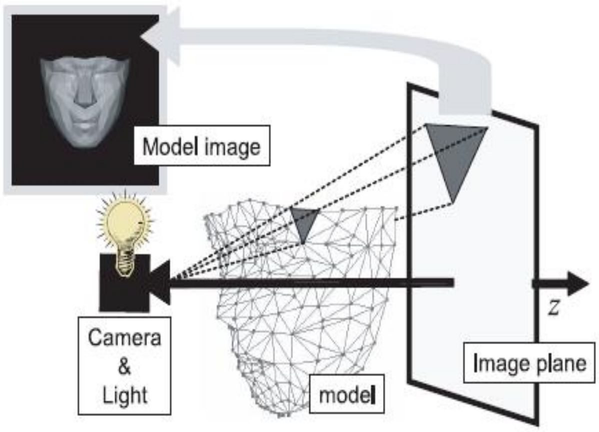


**Figure 2. The Overview of the Face Model**

Let **'‾T'** be the average face shape of the database, **Pn** be the matrix of the first **n** eigenvectors **P** attain a 90 % contributing rate, and **'b'** the vector of the first **n** eigenvalues. In the equation (1) **T** represents the reconstructed 3D shape. In order to reconstruct a 3D input image we are required to make a model image, which consists of 3D vertices and patch information of the database. About 6 parameters, including 3D position and pose to camera plane were required to make the model image. The overview of model image is elaborated in Figure 2. We consider perspective projection for the camera and apply lambert and Phong reflection models to surface models.

$$I = Iin\ (Ka \cos \theta + Kb \ cosu\ \varphi) \quad (2)$$

We consider Iin, Ka, Kb and **'u'** experimentally. The 3D model phenomenon is graphically described in the figure below. We used the cost function **C** experimentally for optimization. Purpose a, b are weighting factors provided by experimental evolution.

$$C = a\ (1 - Ce) + bCf \quad (3)$$

The Downhill Simplex method has been used to minimize the cost function [25]. Finally, we supposed the estimated parameters for experiments of the face model from single input shade images. PCA was applicable on vertices vectors, and the first 20 Eigen vector were used for reconstruction. The algorithm's accuracy depended on the input image of model to reduce the errors. The error occurred by our method, before and after, is given in the table below.

**Table 1. Errors of All Vertices**

| | average error | | variance | |
|---|---|---|---|---|
| sample | before | after | before | after |
| 1 | 7.65 | 3.65 | 39.37 | 9.33 |
| 2 | 2.19 | 2.11 | 2.21 | 2.03 |
| 3 | 3.85 | 2.40 | 6.52 | 3.80 |
| 4 | 3.01 | 2.12 | 5.35 | 2.24 |
| 5 | 4.67 | 2.90 | 11.24 | 5.68 |
| 6 | 4.43 | 2.57 | 12.16 | 3.65 |
| average | 4.30 | 2.63 | – | – |

We chose six images randomly from the database and applied our methods to it, on the basis that the above data set we get the following results shown in the figure below.

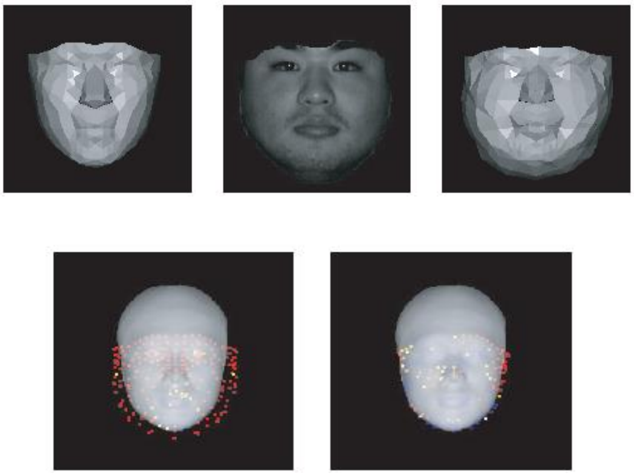

**Figure 3. Right: Reconstructed Vertices and Final Image**

## 4. Technical Discussion

The execution of the 3D reconstruction techniques depends on different databases because of various inner structures and the complexity of databases. Therefore a new method developed for specific databases in order to reduce the number of errors and improve the performance of databases. We are focused to measure the execution of three-dimensional face shape algorithms from isolated images. Two standard methods have been briefly discussed in literature based on PCA (Principal Component Analysis), others follow Lambertian reflectance performed on different databases introduced in [11-13].

### 4.1. Procedure Comparison

Firstly, we measured the performance of different algorithms based on different databases as shown in Table 1.

### 4.2. Merits and Demerits

In this article 3D reconstruction faces from single images by USF databases were implemented and represents the similarities of faces by using shading information. There is also no need of correspondences among the faces and storing of faces in databases. While on the other side, 3D face reconstructed using anatomical database minimized the parameter estimation issues of PCA and reduced the shading problems. We consider the 3D face model quite similar to 3D scanners but still more improvements are required for better results.

### A. Factors Influence the Performance

Factors affecting the performance can be classified as intrinsic and extrinsic. The main factor that influences the performances of algorithms are experimental set ups, lighting, alignments, albedo, recovery boundary conditions and depth. In order to quantify these factors, we implement the USF database [14] Anatomical and Yale B databases [15] in the literature.

**Table 2. Comparison with USF, Yale B & Anatomical Database in Literature**

| Method | Database | Accuracy |
|---|---|---|
| 3D face shape Model | USF Database | 3.2 ± 2.7% |
| | | 2.9 ± 1.9% |
| | | 3.1 ± 2.3% |
| | | 4.1 ± 2.7% |
| | YaleB Database | 6.9 ± 5.6% |
| | | 6.2 ± 5.9% |
| | | 5.9 ± 4.6% |
| | | 5.3 ± 4.9% |
| | Anatomical Database | 9.33 |
| | | 3.80 |
| | | 5.68 |
| | | 3.65 |

### 4.3. Experimental Set Up

The design of the experiment is very essential for accurate results and algorithms based on USF database we used 1100Mhz work station, AMD quad-core 2354 processor, some parameters were kept constant throughout, such as the reference albedo and 2-D Gaussian *etc.* We tested our algorithms on Matlab and input images taken under controlling view and single reference model is very important for these methods. Anatomical database experimental set up is defined in Figure 2.

### 4.4. Lighting Variations

The Yale B database among one of databases is explored extensively. It requires a huge number of lighting conditions for different poses. The Originally Yale B databases were used for facial expressions and collecting of different face samples. These trends begin with the fact that changes in light variations affect the appearance of the face [16].

### 4.5. Depth Information

The third important source is depth recovery. Texture and depth information have strong correlations in structural geometry. Since we have a reference model, a sensible approach is to use its depth values zref (x, y) as Dirichlet boundary conditions, or, alternatively, the derivatives of the reference along the boundaries as Neumann boundary conditions. These constraints, however, are too restrictive, since the depth values of the reference model and their derivatives may be incompatible with the sought solution. Depth color correlation is informative for depth recovery.

### 4.6. Extension of Work

It has been verified that the 3D face model created from the USF database is more accurate and efficient than the anatomical database 3D face. The image quality is much better, and there are fewer chances of error. The work has been even more improved by using different parameters and amendments in mathematical formulas. For optimization purposes, different mathematical equations can be used. This method is only applicable to the face, but the same methods can be implemented on objects in which a 3D prototype will provided for reconstruction. The algorithm results implemented on Yale B database can be further applicable to the CASIA 3D database. By controlling reference model, lighting estimation and pose the performance of algorithms will be faster and more efficient.

 

# 5. Three Dimensional Face Reconstruction

## 5.1. 3D Model-based Algorithms

The morphable model is considered to be an important area of facial recognition. In the last ten years, the 3D morphable model has been studied and explored extensively. Researchers have published different approaches, but improvement in that field is still needed. Optical flow algorithms were initially developed by Blanz and Vetter for the three-dimensional morphabale face model [17] and the Spare deforming model introduced by Gao *et. al.,* [18]. The components and features of the model of whole shape were explored by Ding *et. al.,* [19] in order to avoid errors and achieve the maximum performance and reduce complexity. A major work had been done by Nixon *et. al.,* [20] in automation of removing the partial noise in occlusion areas before the model's construction. Further work promoted by different writers .soon Jiang *et. al.,* [21] modified the algorithms of 3D morphable models and analyzed with various approaches of reconstruction which is full automatic and efficient. Realistic 3D face models were created by using prototype faces, such as even single images, a similar model for the targeted facial image. Compared with facial traditional algorithms [22], on the other hand Patel and smith [23] focus on accuracy manual labeled facial feature points. A famous model of three-dimensional facial reconstruction was detailed elaborated in [35]. 3D laser scanners were used for different purposes to study a statistical space of shape and texture deformation. Some of methods involved to analyzed frame-to-frame motion in videos recovered pose and non-rigid deformations for tracking faces [24]. Optical flow along with the constraints simplified from deformable models [25]. Although iterative optimization in this process is computationally expensive, the same method can also be used to fit a morphable face. Different authors provide various theories about reconstruction. 3D range of scans in a cylindrical parameterization $r(h, \varphi)$ [26]. Konstantinos Rematas's [27] work on the synthesis of images and improved, novel view of unknown instances of this class. Additional applications were 2D-to-3D conversion, super resolution and non-local smoothing.

## 5.2. 3D Shape-based Algorithms

3D shape reconstructing is one of the most important issues in computer graphics. Several approaches have been introduced to recover the shape *e.g.,* surface gradient, depth, surface slant and normal surface *etc.* The methodologies used to rebuild the shape are known as shape-from-X techniques and where X represents motion, texture, stereo and shading. There has been a substantial amount of work regarding statistical shape recovery of the human face modelling and biomedical structures with distinct shapes [28]. Mingolla and Todd's Mingolla and Todd's study of the human visual system based on the perception of solid shapes [29]. Horn, Szeliski and Yuille discovered that some impossibly shaded images exist, which could not be shaded images of any smooth surface under the assumption of uniform rectance properties and lighting. For these kind of images, the SFS will not provide a correct solution, so it is necessary to detect impossibly shaded images [30]. Castelan *et. al.,* [31] developed a coupled statistical model that can recover the 3D shape from the intensity of images by using a series of matrix operations. Nonetheless, it cannot handle unknown illumination. Reconstructing a 3D bone shape from a restricted number of 2D X-ray images is a challenging task, especially when reconstructing a patient bone specific surface. Moreover, for surgical application, high accuracy reconstruction is required. The error of reconstruction has to be in the range of surgical usability [32] in manual alignment between each training tooth and a generic tooth was done in order to have point-to-point correspondence between different specimens. A point distribution model was then computed by using PCA to describe the shape. The morphable model framework of estimates the shape and the texture coefficients from an input 2D image, together with other.

## 6. Discussion and Conclusion

Multiple factors are involved in 3D face reconstruction, such as spatial resolution, speed, flexibility in capturing data, sensitivity to noise deliverance along with 3D data and format *etc.* To affect the performance and accuracy of three-dimensional methodologies, many algorithms are developed for this purpose. It is considered that 3D range scanner demonstrate the high quality of three-dimensional methods specifically for recovering realistic face modeling. The main issues with scanners are their high price and complex environmentally- controlled conditions. On the other hand, image based methodologies are at a low price and are adoptable in simple and general conditions. As considered in biometric based security applications and algorithms, reconstructed images could be scanned for driving licenses and image sequences from a video surveillance camera *etc.* Many types of images are beneficial for different techniques as single image, shape from motion, shape from shading and model based methodologies are helpful in 3D face modeling. Shape from structure can rebuild the face for applications, which demand high-quality face models (such as enrollment under favorable condition). Reconstruction using the active range scanner is the most favorable option. The accuracy of active scanners makes them the current scanner of choice for most research applications. However, if the performance of passive scanners is improved, they will become the scanner of choice because they are more versatile, require less calibration, and are much less expensive than active scanners. In this article, an overview of most important three-dimensional face algorithms along with databases has been provided. The availability of these techniques worked as a catalyst for development of facial modeling. These algorithms are tested on different databases however it is important to measure the performance when compared with one another.

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