Non-uniform Face Mesh for 3D Face Recognition

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ABSTRACT

Uniform face meshes are able to represent the face in 3D format and can also be used to perform 3D face recognition. However, to obtain a good recognition rate, a fine mesh which consists of many points would be needed to accurately represent the many contours of the face. Therefore, in this paper, it is proposed that a non-uniform face mesh is constructed for 3D face recognition. A non-uniform mesh consisting of fine meshes for the middle of the face and coarse meshes for the rest of the face was created. In comparison with a uniform mesh, the proposed non-uniform face mesh consists of much fewer points and therefore saves storage space and transmission time due to a smaller file size. Besides that, the proposed mesh was able to produce recognition rates that were only slightly lower than the uniform mesh, hence proving that important face features for recognition were retained.

Keywords
Face mesh, Face recognition

1.0 INTRODUCTION

Face recognition is an important area that has been researched on for many years. A face recognition system can be used to identify dangerous people in a crowd or to verify the identity of a person. In the past, face recognition systems uses 2D images to perform identification (Turk & Pentland, 1991; Belhumeur, Hespanha & Kriegman, 1997). Although 2D images can produce good results, they still suffer from a few problems, like illumination and pose changes (Zhao, Chellappa, Rosenfeld & Phillips, 2000). Therefore, researchers started to focus on using 3D images to solve face recognition problems. This is because 3D images can be rotated in different angles and therefore solves the pose changes problem.

3D images are usually captured using 3D scanners and can be kept in a variety of formats. Different format will suit different applications and methods of usage. These formats include point clouds, polygonal models and 2.5D point matrix or range images (Colbry, 2006). Point clouds are a set of points in a space, polygonal models, or meshes, are like point cloud, but with the extra neighbour information while range image is actually a point cloud in a matrix (Colbry, 2006). This type of matrix needs a corresponding flag matrix that indicates whether that position in the matrix has a valid data or not.

Range image is able to represent the face accurately and has been used for 3D face recognition. They are able to show the exact contours of the face when the point matrix is dense enough. However, the image size can be huge due to the amount of data stored which takes up storage space or causes long transmission time. Besides that, some area of the face may not need a large amount of points to represent it, causing some points to be redundant.

Therefore, face meshes have been proposed in the past to represent a 3D face image for face recognition, as shown by (Xu, Wang, Tan & Quan, 2004), since they require less points. A typical mesh consists of many uniform little triangles that cover the whole face. Basically, three points of a triangle in a mesh is able to represent a face area which may contain many points from a range image. (Xu et al., 2004) method converts a point cloud face into a mesh, first by using a coarse mesh and then subsequently refining it to a finer dense mesh to represent a face. After that, recognition is done using the face meshes. Although recognition usually concentrate on the face features like the eyes, nose and mouth, the whole face was converted into a finer dense mesh for recognition.

Therefore, in this paper, it is proposed that a 3D face represented by range images be converted to a non-uniform face mesh which consists of fine meshes in the eye, nose and mouth areas while the rest of the face is represented by a coarse mesh. This is because the middle area of the face contains many contours and is crucial for face recognition while the rest of the face like the forehead and chin area is relatively smooth. If a uniform face mesh is used, then the whole face will need to be covered by a fine mesh to cater for the middle part of the face. With a non-uniform face mesh, which face area that needs a fine mesh and which face area that needs a coarse mesh can be controlled.

The proposed method is able to reduce the number of points needed to represent the face, hence saving storage space and reducing transmission time. Besides that, the recognition rate would not be severely affected, as shown in the experimental results.

Section 2 discusses about construction of the non-uniform face mesh while Section 3 discusses about fitting the face mesh to the range image. Section 4 discusses the method for face recognition, Section 5 shows the experimental results and finally the conclusion is in Section 6.

2.0 FACE MESH CONSTRUCTION

Instead of using a standard face mesh and fitting it according to face features location, a simple non-uniform face mesh is constructed instead. This mesh consists of 3 sections, which are the top, middle and bottom sections. The top section is from the top of the head till the eye level, the middle section is from the eye level to the mouth level and the bottom section is from the mouth level to the chin level. The top and bottom sections consist of a coarse mesh while the middle section consists of a fine mesh. This is because the middle part of the face between the eyes and mouth contains a lot of face information and many contours. Therefore, it is crucial that a finer mesh is placed in this area to give a better representation of the face. However, for the forehead and chin areas, there are not much contour changes and therefore a coarser mesh for these areas is sufficient. The basic non-uniform mesh is shown in Figure 1.

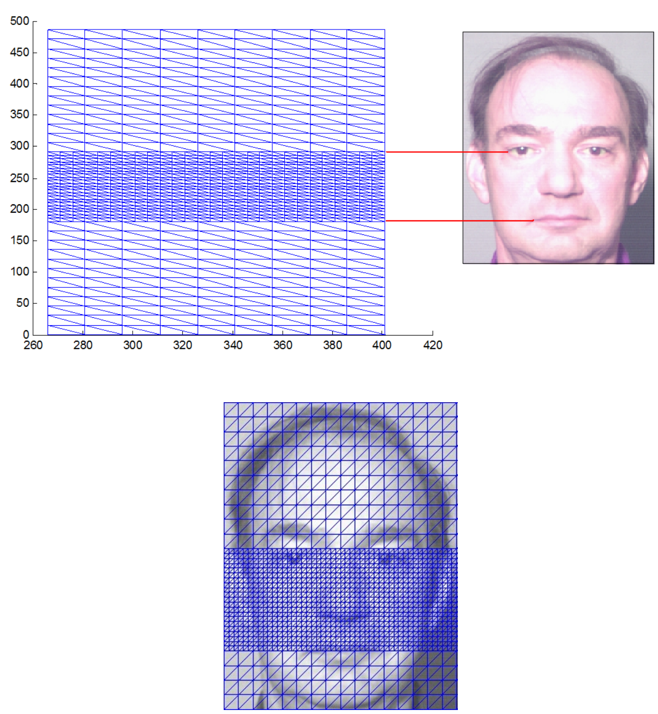

Figure 1: Basic non-uniform mesh

The mesh created in Figure 1 has a fine mesh size which is 3 times smaller than the coarse mesh. The size of the whole mesh is the same as the size of the image. In this paper, the eye and mouth level were determined manually using the corresponding 2D images of the 3D range image but this can be easily be done automatically using some face feature detection algorithm. After obtaining this basic non-uniform mesh, the next step is fitting it to a face range image.

3.0 FITTING FACE MESH TO RANGE IMAGE

At the moment, the basic mesh z-coordinate is still at zero. Therefore, the next step is to match each mesh point z-coordinate with the corresponding range image. This is done using the least square fitting method (Weisstein; Eberly, 2008). Firstly, the mesh created is superimposed on the range image. Then, for each triangle in the mesh, it is determined if there is a group of range values within the triangle boundary. If there are no range values, then this individual triangle is removed from the mesh.

For those that have a group of range values, the next step is to determine the plane equation for each group of points using equation (1) (Bourke, 1989).

$$Ax + By + Cz + D = 0 \qquad (1)$$

where the normal to the plane is the vector (A,B,C).

Equation (1) shows the plane equation obtained from a group of range image points. Therefore, to estimate the z coordinates of each mesh triangle, the 3 pairs of x and y coordinates are inserted into the equation to obtain each z values. This results in a mesh that has different depth at different points, corresponding to the range image. However, the mesh is still disjointed since each triangle depth value may not correspond to the neighbouring triangle depth value, as shown in Figure 2.

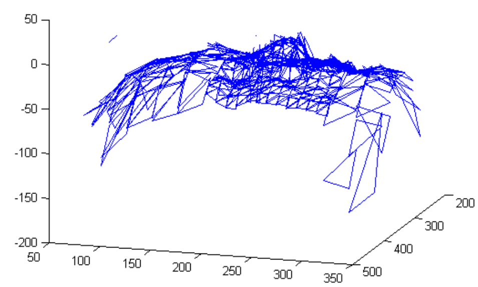

Figure 2: Disjointed face mesh

To smoothen out the mesh, all the z-coordinates at the same location are recorded and the final z-coordinate value at that location is the median of all the values. To eliminate outliers in the face mesh, all the z-coordinates must be more than Q1-(1.5xIQR) and less than Q3+(1.5xIQR) where Q1, Q3 and IQR are the 1st quartile, 3rd quartile and inter-quartile range respectively. The final face mesh is shown in Figure 3.

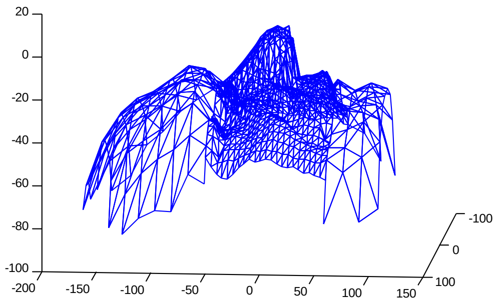

Figure 3: Proposed non-uniform face mesh

4.0 FACE RECOGNITION

Face recognition is achieved by comparing two face meshes together and calculating the distance between them. In this paper, the comparison method used consists of aligning the probe and database meshes together, find the distance of each point on the probe with the mesh and calculating the mean square value of all the distances combined. Since each point in the probe might not have a corresponding point in the database mesh to determine their distance, an estimate of the corresponding point is needed. This is obtained by first determining which triangle area does the probe point falls in. Once the triangle is found, the triangle plane equation is calculated using the equation (2), (3), (4) and (5) (Bourke, 1989).

$$A = y1(z2 - z3) + y2(z3 - z1) + y3(z1 - z2) \quad (2)$$
$$B = z1(x2 - x3) + z2(x3 - x1) + z3(x1 - x2) \quad (3)$$
$$C = x1(y2 - y3) + x2(y3 - y1) + x3 (y1 - y2) \quad (4)$$
$$D = -(x1(y2z3 - y3z2) + x2(y3z1 - y1z3) + x3(y1z2 - y2z1)) \quad (5)$$

where (x1,y1), (x2,y2) and (x3,y3) are the 3 corner points of the triangle.

Once the above information is calculated, the plane equation of the triangle is known. Then, by inserting the x and y coordinate of the investigated probe point into the plane equation, the z coordinate of the database mesh at that location is obtained and the distance between the probe and database mesh at that point is determined.

5.0 RESULTS

To prove the effectiveness of the proposed non-uniform face mesh for face recognition, the face recognition experiment was performed on 3 different types of face meshes. The first type is a uniform fine mesh and contains all small triangles, the second mesh is a uniform coarse mesh and contains all large triangles while the third mesh is the proposed non-uniform face mesh, which consists of both fine and coarse meshes. The fine mesh, coarse mesh and non-uniform face mesh contains about 20%, 5% and 10% of the amount of range image points respectively. Figure 4 and Figure 5 shows examples of a fine mesh and a coarse mesh.

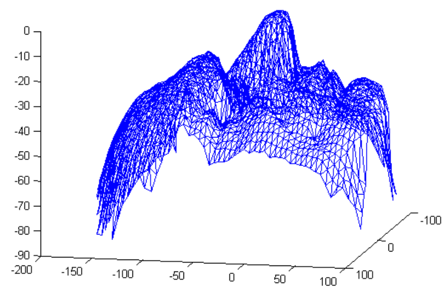

Figure 4: Uniform fine face mesh

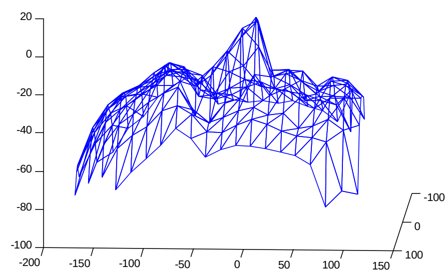

Figure 5: Uniform coarse face mesh

In this paper, the UND face database was used (Flynn, Bowyer & Phillips, 2003; Chang, Bowyer & Flynn, 2003). This database stores their face images in range image format. A total of 50 images were used as the database and 30 images were used as the probes. Firstly, these images were converted and fitted to face meshes and then face recognition was performed on them. The final result is shown in Table 1.

Table 1: *Face recognition rate*

Rank	Uniform Coarse Mesh	Uniform Fine Mesh	Proposed Non-uniform Mesh
1	20%	60%	53%
2	47%	73%	60%
3	67%	87%	60%
4	80%	93%	87%
5	80%	93%	87%

From the results obtained in Table 1, it can be observed that the coarse mesh had the worst recognition rate and there is only slight difference between the recognition rate of fine mesh and proposed mesh.

The recognition rate of the uniform coarse mesh is not high probably due to the coarse mesh is unable to sufficiently represent the finer contours of the face around the eye, nose and mouth area. Since these areas help differentiate one face to another, therefore, it is crucial for this area to be properly reconstructed.

For the uniform fine mesh, recognition rate is high due to the whole face is properly reconstructed by the mesh, including the finer contours of the face. However, to represent the whole face using only a uniform fine mesh requires a high number of points, which means the file size of the mesh is big. This can pose storage and transmission problems.

Therefore, it was proposed in this paper that the face be represented by a mesh that contains a combination of coarse and fine meshes. The multiple contour areas are represented by fine meshes while the rest of the face by coarse meshes. This helps optimize the mesh used to represent the face and reduces the number of points for the face mesh when compared to a fully fine mesh, yet does not greatly affect the face recognition rate. The results obtained shows that the proposed method is a feasible method.

6.0 CONCLUSION

In this paper, it was proposed that 3D face images represented using range images be converted to a non-uniform face mesh to perform face recognition. Firstly, a basic mesh which has a combination of coarse and fine mesh was created. The fine mesh encapsulates the eye, nose and mouth area while the coarse mesh is for the rest of the face. This mesh was then fitted onto a face range image to obtain a face mesh. After all the database and probe range images were converted to face meshes, face recognition was performed. The recognition method used in this paper consists of aligning the probe and database mesh together and calculating the mean distance between them. From the results obtained, it is observed that the non-uniform face mesh produces recognition rates that are only slightly lower than when a uniform fine mesh was used. However, only half the amount of points is needed to represent the non-uniform face mesh when compared to the uniform fine face mesh. Therefore, this shows that the face mesh can be simplified but yet retains the important face features to produce good recognition rates. The main advantage in using a combination mesh is reduction in the number of points representing the face, which in turn helps save storage space and transmission time.

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