Face Shape Classification from 3D Human Data by using SVM

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***Abstract*—Face shape is also important information for glasses design companies. In this paper, we proposed a non-contact method to classify the face shape by using Support Vector Machine (SVM) technique. This algorithm consists of three steps: head segmentation, face plane identification, and face shape classification. First, as whole 3D body data is captured and used as input of system, Eigenvector is used to define frontal side. Chin-Neck junction, Ellipsoid Fitting Technique and Mahalanobis distance are combined as a head segmentation algorithm to segment the 3D head. Second, face shape can be observed when projected on a plane. Major axes of ellipsoid are used to define a plane along the head called the face plane. Face shape on the face plane is classified into four classes in third step. To test the performance of the proposed method, ninety subjects are used. SVM is used to classify the face shape into four groups. The four type of the face shape are ellipse shape, long shape, round shape, and square shape. The accuracy rate is 73.68%. The result shows the feasibility of the proposed method. An advantage of this method is that this method is first fully automatic and non-contact face shape classification for whole 3D human body data.**

Keywords*— *Ellipsoid Fitting Technique, 3D Human Body, Face Plane,

I. INTRODUCTION

Face shape have become very essential information used in many applications such as 3D face synthesis, animation, computer vision, or hat or glasses design [1, 2, 3]. Most similar animation with real face or most suitable design of hat or glassed with the face shape is expected. Especially, for glasses design companies, ratio of each type of the face shape per population is used to make a decision to design glasses for a target group. Therefore, an algorithm to analyze the face shape is needed. Face shape classification from 3D data is more challenge than 2D face image because it is difficult to analyze the face shape from correct direction. Obviously, the face shape has to be analyzed from the frontal face side. In this paper, we aim to classify the face shape from 3D face data.

Some research proposed face shape classification for different application. Y. Xu and et al. proposed a method to measure and classify Shanghai female face shape based on 3D image feature [3]. Young female for 201 cases were divided into eight kinds of the face shapes by cluster analysis using SPSS software. Face features used for classification are facies temporal width, bizygomatic breadth, mandibular breadth, maxilla-chin breadth, and physiognomic facial length. Vitus Smart scanner belonging to Lectra in France is used to measure 3D body. Eight types of face shape are heart shape, round shape, ellipse shape, long shape, pear shape, square shape, diamond shape, and melon seeds shape. This paper aim to prove that all indexes is reasonable for classification of human faces. L. Li and et al. proposed a method to classify face shape for person's expression recognition [4]. An AAM-based method is used to extract the facial feature. Based on the shape parameters of AAM, an SVM-based classification method is proposed to classify the main face shape into three types of face shape: melon seed, round, and square. The result shows that face shape classification can improve the recognition rate. This method uses 2D image as input of system. The 2D face image is captured from frontal face. The frontal face image has been suitable for face shape classification. Additional, W. Rukang, and et al. divides face shape with different number of group and type. W. Rukang, and et al. proposed a method to classify face shape into ten groups: ellipse, ovoid, inverse ovoid, roundness, square, rectangle, diamond, trapezoid, inverse trapezoid, and pentagram shape [5].

An existing research proposed for 22Q11.2 detection syndrome from face image. K. Wilamowska and et al. proposed a method to classify between individuals with 22Q11.2 syndrome and general population based on face data [6]. This method uses 3D face data, and finds the difference of facial features between two groups of data based on shape-based morphology. 3D snapshot, 2.5D depth image, and curved line of face are used for detection. Classification is performed by using feature vectors combining with the Principle Components Analysis. The accuracy rate ranged from 74% to 76%. However, this method is appropriate for data that has been already segmented the head

Based on existing research, the face shape classification is applied for many applications. All of research proposed the method based on the assumption that frontal face direction has been known, and the head has been extracted. It is not appropriate for data in three-dimensional space without frontal face direction identification. Therefore, we propose a new method for face shape classification by using SVM techniques. This algorithm consists of three steps: head

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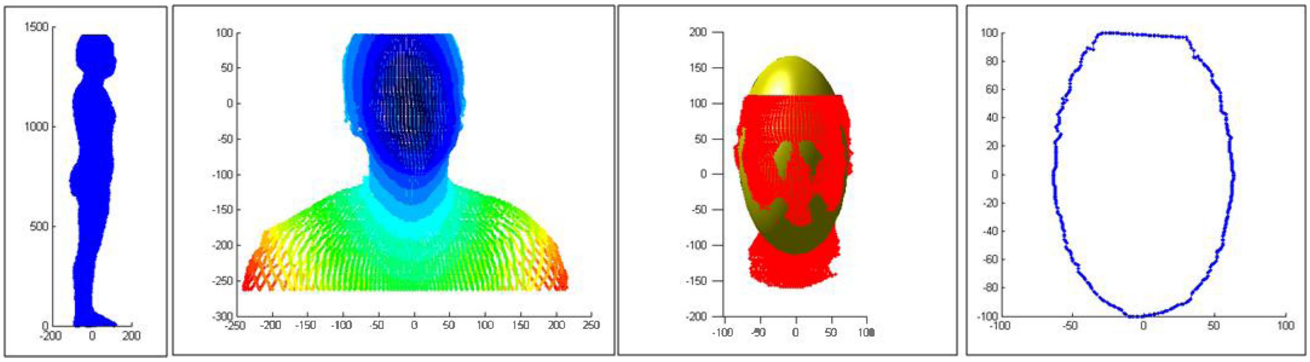


a) Data acquisition b) Head Segmentation c) Face plane computation d) Face shape classification

Fig. 1 Face shape classification method start from a) data acquisition, b) head extraction, c) face plane identification, and d) face shape classification

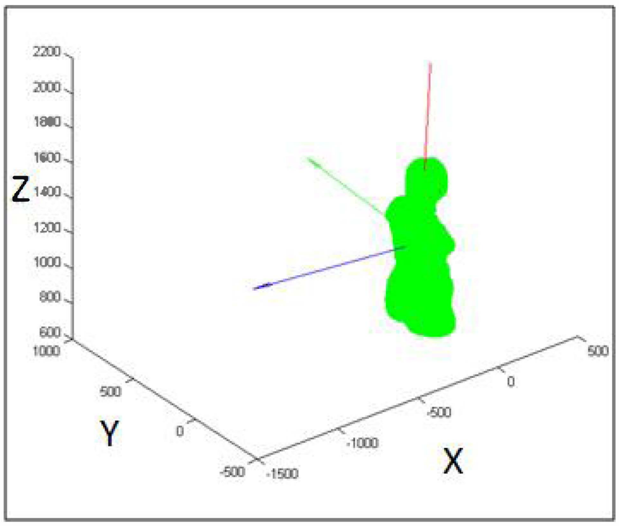


Fig. 2 Three eigenvector derived from whole 3D body to define front side.

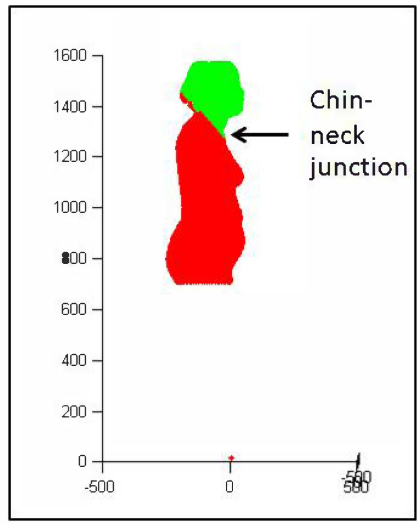


Fig. 3 Chin-neck junction detection

segmentation, face plane identification, and face shape classification. This method is first fully automatic and non-contact system to classify the face shape from whole 3D body data.

The paper is organized as follows: the proposed method is described in section II. In section III, the experimental results are discussed. Finally, section IV concludes.

II. The Face Shape Classification Method

Algoirthm of face shape classification method is shown in Fig. 1. It begin from a) data acquisition, b) head extraction, c) face plane identification, and d) face shape classification. In this section, technique in each step will be described.

A. Data Acquisition

In this research, 3D data of whole human body is collected by Biomedical Signal Processing Laboratory, National Electronics and Computer Technology Center. The input data is captured using $[TC]^2$ 3D body scanner and represented by data points without texture data. A sample result of the whole body is shown in Fig. 1a.

B. Head Segmentation Algorithm

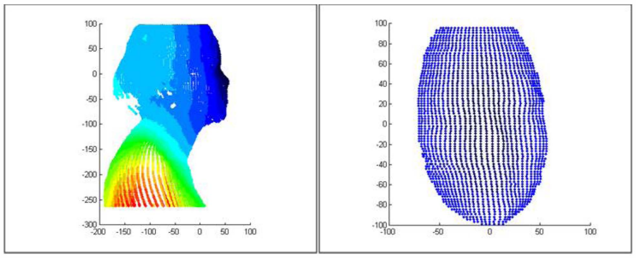
As whole 3D body is scanned, frontal face side is unknown. To define the frontal face side, eigenvector is applied as:

$$A = \frac{1}{N}\sum_{i=1}^{N}(X_i - \mu)(X_i - \mu)^T \quad (1)$$

where $X_i = [x_i; y_i; z_i]$ is coordinate of a point in 3D space, $\mu = [\mu_x; \mu_y; \mu_z]$ is mean coordinate, N is number of points.

By using Eigenvalue and Eigenvector for Eq. 1, three values of eigenvalue (λ): $\lambda_1, \lambda_2, \lambda_3$ and three directions of eigenvector (e): e_1, e_2, e_3 are derived. Eigenvector related with middle eigenvalue is pointed to back or front side of 3D human body. Front side is checked from foot finger. Point on the ground is farthest is defined as foot finger. Vector defined by eigenvector must point from center of body to foot finger direction as shown in Fig. 2. Green, red, and blue color vector are eigenvector. Blue vector is vector pointing to back or front side of 3D body.

Head region that is necessary for face shape classification is the region above the chin-neck junction. To segment the head region, three techniques: chin-neck junction detection, ellipsoid fitting techniques, and Mahalanobis distance



a) b)

Fig. 4. Mahalanobis distance for head segmentation. a) 3D human body with Mahalanobis distance from side view. b) Head region after segmentation from frontal view.

technique are combined as the head segmentation algorithm. To detect chin-neck junction, we find a point from top of head which is curved inwards into human region both from back and front side. The junction passes points both back and front side is defined as the chin-neck junction as shown in Fig. 3. Green region is a part above the chin-neck junction that will be used as data for ellipsoid fitting technique.

In Ref. 7, human head profile is assumed as oval based on observation. Therefore, ellipsoid is used to fit to the head data for defining the head region, and compute the face plane. According to robustness of noise data, least squares ellipsoid fitting technique proposed by Q. Li and J.G. Griffiths [8] is applied in the paper. The theory is summarized as following description.

Generally, an ellipsoid equation is defined from conic equation of the second degree in three variables under a constraint as:

$$F(x,y,z) = ax^2 + by^2 + cz^2 + 2fyz + 2gxz + 2hxy \\ +2px + 2qy + 2rz + d = 0 \quad (2)$$

Let

$$I = a + b + c \quad (3)$$

$$J = ab + bc + ac - f^2 - g^2 - h^2 \quad (4)$$

$$K = \begin{vmatrix} a & h & g \\ h & b & f \\ g & f & c \end{vmatrix} \quad (5)$$

where *F(x,y,z)* is the ellipsoid equation, the parameter *a*, *b*, *c*, *f*, *g*, *h*, *p*, *q*, *r* and *d* are coefficients of the ellipsoid, *(x, y, z)* is coordinates of points on facial surface.

Defined from Eq. 2 as an ellipsoid if

$$kJ > I^2 \quad (6)$$

where k is a positive number. Where $k = 4$, the fitted shape will be an ellipsoid.

According to ellipsoid equation and its coefficient, center of ellipsoid and three axes are computed. Obviously, major axis is defined. Center of ellipsoid will be used as a parameter for computing Mahalanobis distance, while three axes will be used to define the face plane.

Mahalanobis distance is applied to define the head region for more precise head region. The Mahalanobis distance is used to define range of the distance that head points should be located in. The Mahalanobis distance of each point is computed from points of human body. Center of ellipsoid is used as center for computing Mahalanobis distance. Distance of a pixel to center is interpreted as:

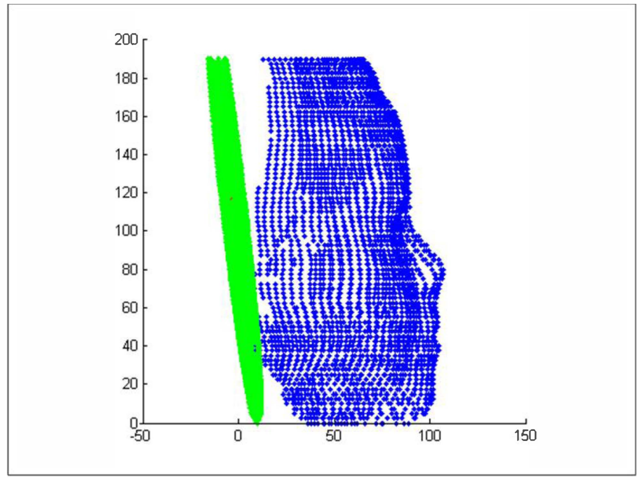


Fig. 5 Face plane computation. Green hyperplane is the face plane. Blue point cloud is 3D face.

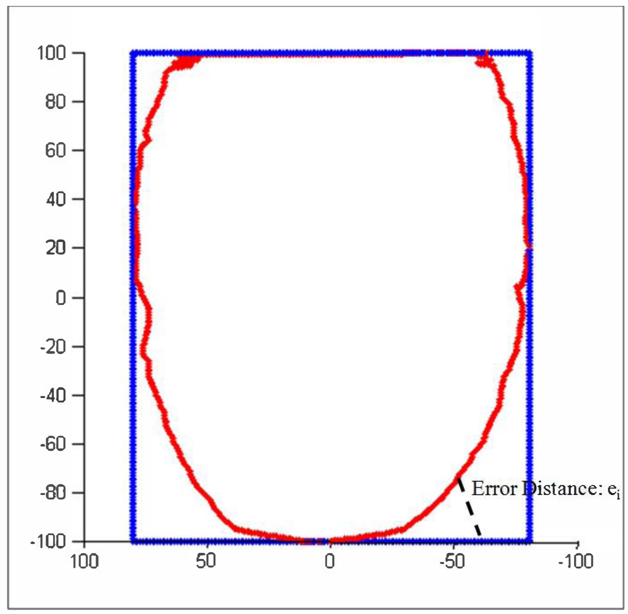


Fig. 6 Error Distance (e_i) measured from a point on the face shape and a point on frame.

$$r^2 = (x - \mu)^t \Sigma^{-1} (x - \mu) \quad (7)$$

where x is a pixel coordinate, μ is center of ellipsoid, Σ is covariance matrix and r is Mahalanobis distance from x to μ. Point with close distance with center of ellipsoid will be shown in blue point in Fig. 2.b., farther points are shown in red color. We set a criterion of Mahalanobis distance to define the head region. The point which has the Mahalanobis distance shorter than the criterion is defined as the head region as shown in Fig. 4.

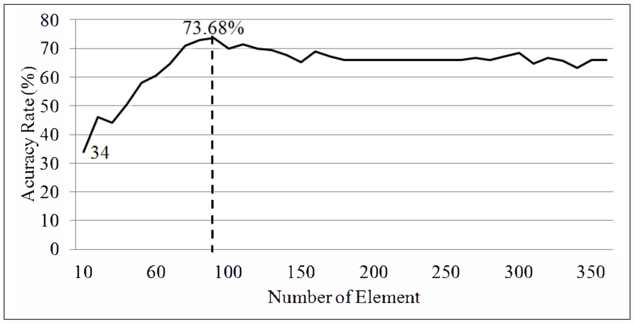


Fig. 7. Experimental Result

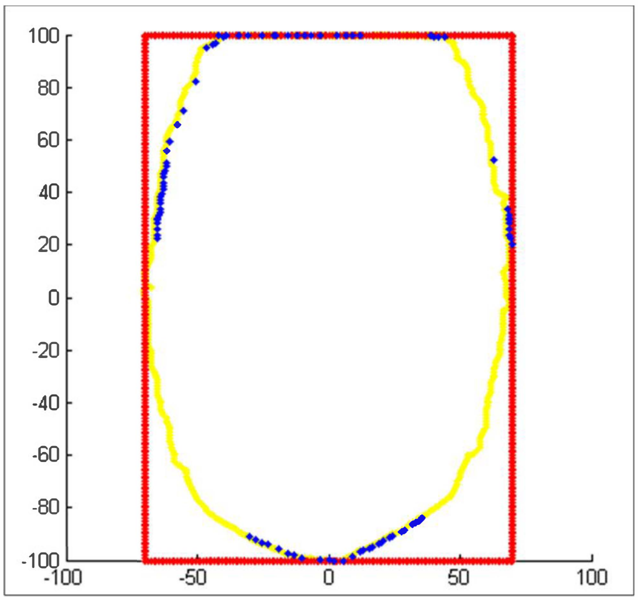


Fig. 8. Position of 91 Significant points. Yellow points are points on face shape. Blue points are the signification points.

C. *Face Plane Computation*

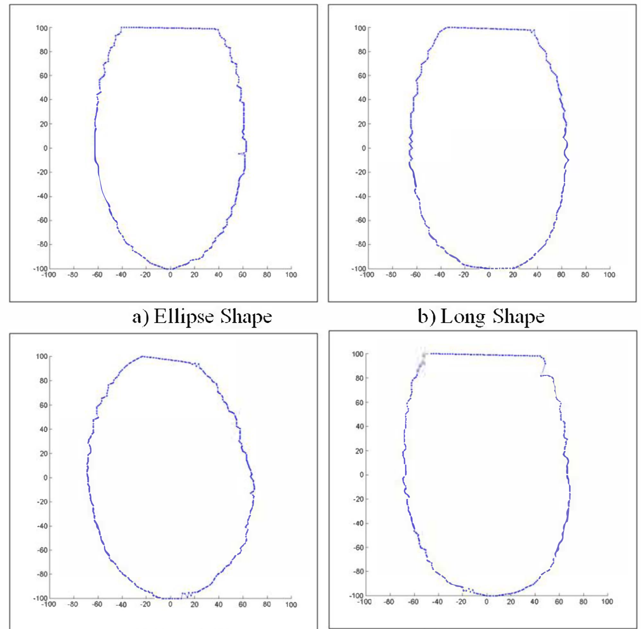
As described in subsection B, three axes are computed from ellipsoid fitting technique. A hyperplane defined as the face plane will be computed from two vectors: a vector on the face plane and a vector pointing from a point on the face plane to frontal direction.

The vector lied on the face plane is eigenvector with maximum Eigenvalue. Another vector pointing to the frontal direction will be computed by comparing with the vector pointing to foot finger direction. The face plane can be computed by these two vectors as shown in Fig. 5.

D. *Face Shape Classification*

For face shape classification, points of face shape on the face plane are considered. Support Vector Machine technique is used for classification.

3D face data is projected onto the face plane. The face shape is appeared on the face plane. A frame covering the face shape is computed as shown in Fig. 6. Distance between a point on the face shape to a closest point on the frame is called the error distance (e_i) as shown in dash line in Fig. 6. 360 error distances are defined based on the angle of 360 degrees. Finally, we use the error distances for SVM method.



a) Ellipse Shape b) Long Shape

c) Round Shape d) Square Shape

Fig. 9 Correct results of the face shape classification

III. Experimental Result and Discussion

To test performance of the proposed method, 3D body data of 209 subjects is used. A hundred subjects are used as training data, remain of subjects is unknown data. The face shape is divided into four types of the face shape: ellipse, long, round, and square face shape. Result is compared with classification by expert.

This experiment aims to measure significant points that give best performance of the proposed method, and measure the accuracy rate. We use PCA technique to arrange each element in a set of data based on its significance for SVM. We found that 91 elements give the best accuracy. The result is shown in Fig. 7. The accuracy rate is 73.68%. Positions of 91 elements are shown in Fig. 8 in blue points. Fig. 9 shows correct results of the face shape classification.

Error rate is 26.32%. There are two causes of error. Incorrect plane of the face plane and noise on the face contribute 20.1% and 6.22% faults, respectively.

IV. Conclusion

In this paper, we propose a new method to classify the face shape from whole 3D body. The support vector machine method is used as classifier. To test the performance of method, data of 209 subjects are used. Face shape is classified into four groups: ellipse, long, round, and square face shape. Accuracy rate is 73.68%. Significant points for classification are located in 91 positions around the face. Incorrect classification occurred from incorrect plane of the face plane, and noise. Comparing with others method, this method has two advantages: fully automatic system, and suitability for using for whole 3D body.

Future work, the accuracy rate should be improved. Face plane will be computed from the method in Ref. 9.

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