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Study on Face Classification and Modeling Based on the Fit Problem of Respirator for Chinese Adults

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***Abstract*—To solve the fit problem between the face and the mask in the market, 7 facial indexes related facial masks of 194 adults were measured in this paper. Factor analysis was undertaken and two main factors were chosen. Through counting the relative index, 3 representative body indexes were selected as clustering variables. K-means cluster was applied to classify the figure type and the optimal number of clusters was determined by Mix-F statistics. Combined with reverse engineering design software, the model was established by using the object of the clustering center value of each index in the class 5 standard face. This study provides practical guidance for the forward design and production of the follow-up mask. The multi-surface modeling of human face has broadened the new thinking to deal with the contradiction between clothing and body.**

Keywords—mask; head-face measurements; facial classification; reverse modeling

I. Introduction

In the context of environmental complexity, the use of masks is increasing, and the research on the dust filtration performance of scholars has also increased, which tends to be saturated. However, there are gaps in the study of suitability. According to the literature [1-2], the sealing ability of the mask is the premise of realizing its anti-dust filtering function. If the sealing is poor, according to the principle of fluid mechanics, airflow will first flow to the low resistance, and the mask will lose the filtering effect. Therefore, in order to solve the problem of compactness, it is necessary to carry out measurement and model analysis on the related indicators of human head and face.

II. The Experimental Measurements

A. Determining Sample Size

According to the *ISO15535-2003, "Establish the sample size requirement of human head database"*[3], *The calculation formula of maximum sample size is as follows:*

$$n = \left(\frac{1.96 \times \sigma}{\Delta} \right)^2 \tag{1}$$

The maximum sample size is n=166. According to the random sampling method, the study selected 200 adults aged 18 to 29 (87 males and 113 females), among which 6 were excluded from invalid samples, and 194 were effectively measured (84 male and 110 female).

B. Methods and Requirements of Measurement.

In this paper, manual contact measurement is adopted, and the main tool is the sliding caliper and the spreading caliper. According to *GB/ T5703-1999 "basic project for human measurement for technical design"*, the location of measurement points is marked on the head[4-7]. The measurement items include: face height, face width, bitragion breadth, bigonial breadth, nose length , nose width, nose depth[8].

III. Statistical Analysis of Results

A. Basic Data Statistics

Table I compares the mean, minimum mode, standard deviation, range and corresponding percentile of 194 effective subjects.

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TABLE I. ANTHROPOMETRIC DATAMM)

Items	$\bar{x}$	Min mode	s	interval	percentile		
					25	50	75
Face height	113.7	110.0	7.2	97.8~141.0	109.0	112.2	118.5
Face width	139.6	132.0	7.6	124.0~163.0	134.0	140.5	144.0
Bitragion breadth	146.1	148.0	11.4	120.0~178.0	138.0	146.5	153.0
bigonial breadth	118.7	123.0	10.7	91.5~151.0	113.0	146.5	153.0
nose length	46.7	39.0	6.1	31.0~59.8	42.1	46.9	51.1
nose width	42.0	38.0	4.4	23.6~52.0	39.6	42.4	45.2
nose depth	20.8	20.0	2.7	13.0~28.0	19.0	21.0	22.7

B. *Factor Analysis*

- Factor analysis was carried out on the relevant measurement indexes of the above selected masks. The KMO value reached 0.805, which means the data suitable for factor analysis.
- The rotation component matrix of factor analysis is shown in table II. The two main components were extracted.
- The first factor has a large load on the face width, bitragion breadth, and bigonial breadth. The second factor has a large load on nose length , nose width, nose depth. Therefore, the two factors actually represent the facial size and the extent of the nose.

TABLE II. ROTATION COMPONENT MATRI

Indexes	Main factors	
	1	*2*
nose depth	-0.070	0.744
nose width	0.228	0.713
nose length	-0.052	0.849
Face width	0.789	0.271
Face height	0.493	0.396
bigonial breadth	0.813	-0.111
Bitragion breadth	0.873	-0.109

C. *Head Cluster Analysis*

- By adopting the most relevant index method, the representative indexes with the most abundant information are selected from the above two categories of factors. Using correlation index formula (2) to calculate the correlation index of each index to other indexes of similar factors, the index with the highest correlation index is used as the representative clustering index, and the results are shown in table III.

$$R_j^2 = \frac{\sum r_{ij}^2}{m-1} \qquad j = 1,2,\dots,m \tag{2}$$

TABLE III. RELATIVE INDEX OF FACE AND NOSE

Indexes of facial factor			Indexes of nose factor		
Face width	***bigonial breadth***	***Bitragion breadth***	***nose depth***	***nose width***	***nose length***
0.30	0.30	0.34	0.15	0.17	0.21

- The optimal classification number [9-10] was determined by using mixed F statistics (FMixed). FMixed is a generalization of the degree of closeness and inter-class dispersion in all variables. The larger the value is, the closer the connection is within the class of all variables, and the more dispersed the interclass connections are. That is, when the FMixed value is the largest, the corresponding classification number is the optimal classification number, and its calculation formula is as follows:

$$F_{Mixed} = \sum_{k=1}^{P} \frac{\frac{1}{F(k)}}{\sum_{k=1}^{P} \frac{1}{F(k)}} = \frac{P}{\sum_{K=1}^{P} \frac{1}{F(k)}} \tag{3}$$

In the formula: *P* is the number of variables of clustering; *F(k)* is the F value of the Kth cluster variable, which can be calculated by formula (4).

$$F(k) = \frac{\sum_{i=1}^{c} n_i \left(v_{ik} - \bar{v_k}\right) \times (n-c)}{\sum_{i=1}^{c} \sum_{j=1}^{n_i} \left(x_{ijk} - \bar{v_{ik}}\right)^2 \times (c-1)} \qquad k = 1,2,\dots,p \tag{4}$$

In the above equation: *c* is the clustering number; *n* is the total sample size; n_i is the sample number of the class i; v_{ik} is the clustering center of the k-th variable of class i sample; The average value of v_{ki} is the average value in the kth variable center.x_{ijk} is the Kth variable value of the Jth sample.

- Table IV shows the F_{Mixed} values corresponding to each category number (c). When c is 5, the corresponding FMixed value is the largest, so 194 adult faces are divided into 5 categories.

D. Contrast and Analysis of Different Face Shapes

- The clustering center values and frequency statistics of various types of face shapes were summarized in table V.
- After comparison of the characteristics of various facial features, it was found that the first class had a small horizontal circumference, and the length of the morphological surface and the longitudinal size of the nose were of moderate deviation.
- The horizontal dimension of the second class is at medium level, while the length of the morphological surface and the longitudinal dimension of the nose are short.
- The third kind of transverse dimension is wider, the overall face is the longest, but the nose is shorter;
- The fourth type is the broadest, and the overall length and nose length are longer.
- Category 5 is the narrowest, with a medium and short length, which can be used as the standard face.
- As a whole, we can see that our adult face shape is short and narrow. However, the uniform size design of the mask in the market is not consistent with that, so we need to further study the facial model.

TABLE IV. F_{MIXED} VALUES OF DIFFERENT CLUSTER NUMBER

Cluster Number	2	3	4	5	6	7	8	9	10
F_{Mixed}	8.07	56.77	66.07	76.90	55.85	63.76	53.68	60.30	68.04.

TABLE V. FINAL CLUSTER CENTERS

Types	nose length	Bitragion breadth	Face height	Frequency
1	5.15	14.64	11.81	51
2	4.11	15.12	10.91	48
3	4.09	15.84	12.16	19
4	5.34	16.51	12.15	14
5	4.73	13.37	10.95	62

IV. REVERSE MODELING

A. The Building of the Triangle Model

Combined with the human body scanner equipment[11], we selected a subject of each index to be close to the 5th class cluster center, so as to conduct the reverse modeling operation. First, the scanned ASC point cloud files are preprocessed, including point coloring, noise removal and redundancy, and simplified filtration. Due to the feature of multi-curved face, the maximum triangular number is set to 1 million to ensure that the polygonal mesh is tightly packed[12]. Later, the encapsulated triangular faces are saved as STL format, as shown in the figure below.

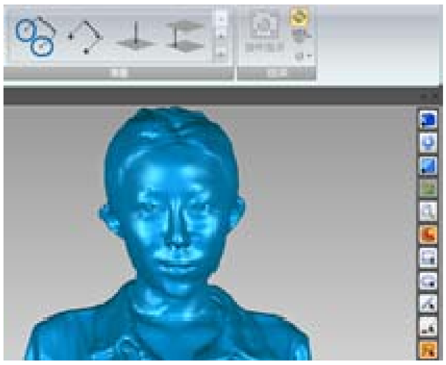

FIGURE I. THE TRIANGLE MODEL OF THE HEAD

B. The Establishment of the Head Entity Model

In addition to the face, the redundant parts are cut. Then the rest is sealed off, and the coordinate system is constructed to create the fitting surface. The specific operation is to select part of the grid surface from the grid surface and use the selected grid surface as the reference water plane, namely the datum plane, through the "fitting plane" tool. On the datum plane, the vertical line of the line of parallel to the earlobe and the tip of the nasal tip is the XY axis. After determining the positive direction, the upward stretch produces three mutually perpendicular planes. The curve mesh is automatically created on the surface and the surface is fitted to the grid to maintain the precision of the underlying grid. Finally, the generated entity is saved as STP format file, which can be used for the forward design head model of the mask, as shown in figure II

FIGURE II. ENTITY OF HEAD-FACE MODEL

V. CONCLUSION

In this article, those indexes related to design and production of mask of 194 adults were measured. The adults' face of our country is divided into 5 categories with the selected representative indicators. After comparison, we found that our adult faces are mostly small,which is not consistent with the large face masks of the present market. Reverse modeling of the standard face shape with the most frequency helps to find a new way to solve the suitability of the mask and face.

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