사상체질 판별을 위한 측면 얼굴 이미지에서의 특징 검출☆

Side Face Features' Biometrics for Sasang Constitution

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요 약

사상의학에서는 사람을 네 종류로 구분하며, 한의사들은 종종 이 네 종류에 기반을 두어 특별한 건강 정보와 치료 방법을 제안한다. 얼굴의 특징 비율(표 1)은 사상체질을 판단하는데 있어서 매우 중요한 기준으로 사용되는데, 본 논문에서는 측면얼굴에서 특징 비율을 추출하기 위한 시스템을 제안하였다. 특징 비율을 얻기 위해서는 두 가지를 고려하여야 한다. 하나는 대표 특징들을 선택하는 것이고, 다른 하나는 측면 얼굴 이미지에서 효과적으로 관심 영역을 검출하고, 정확하게 특징 비율을 계산하는 것이다. 논 논문에서 제시한 시스템에서는 적응형 색상 모델을 사용하여 배경에서 측면 얼굴을 분리하였고, 관심 영역 검출을 위해서 기하 모델에 기반한 방법이 사용되었다. 또한 이미지 크기와 머리 포즈에 따른 이미지 변화에 의해서 야기되는 에러 분석을 제시하였다. 제시한 시스템의 성능을 평가하기 위하여 173명의 한국인 왼쪽 얼굴 사진을 이용하여 시스템을 테스트하였고, 정면 사진과 측면 사진을 함께 사용하였을 경우 정면 사진 만을 사용한 경우보다 17.99%의 성능 향상을 나타내었다.

Abstract

There are four types of human beings according to the Sasang Typology. Oriental medical doctors frequently prescribe healthcare information and treatment depending on one's type. The feature ratios (Table 1) on the human face are the most important criterions to decide which type a patient is. In this paper, we proposed a system to extract these feature ratios from the people's side face. There are two challenges in acquiring the feature ratio: one that selecting representative features; the other, that detecting region of interest from human profile facial image effectively and calculating the feature ratio accurately. In our system, an adaptive color model is used to separate human side face from background, and the method based on geometrical model is designed for region of interest detection. Then we present the error analysis caused by image variation in terms of image size and head pose. To verify the efficiency of the system proposed in this paper, several experiments are conducted using about 173 korean's left side facial photographs. Experiment results shows that the accuracy of our system is increased 17.99% after we combine the front face features with the side face features, instead of using the front face features only.

☞ KeyWords: Side Face, Feature Ratios, Sasang Constitution, Feature detection, Color Model.

1. Introduction

The Sasang constitution is a traditional typology theory in Oriental Medicine. It explains the individual differences in behavioral patterns, physical characteristics and susceptibility to a certain disease based on their bio-psychological traits. This medical typology divides human being into four types based on their traits: Tae-Yang, So-Yang, Tae-Eum and So-Eum type. The nature of each type comes from

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☆ 본 연구는 문화관광부 및 한국문화콘텐츠진흥원의 문화콘텐츠기술연구소육성사업의 연구결과로 수행되었음.

four emotions sorrow, anger, gladness and enjoyment respectively. These emotions influence every person's physiological functions and stimulate specific organ developed or underdeveloped. As a result, their healthy and unhealthy signs are determined. For example, The Ephedra sinica is bad for So-Eum type but not bad for Tae-Eum type, and Aconitum is not bad only for So-Eum type [1].

Human being is a complex organism with multiplicity. In order to decide the exact type for every patient, as usual oriental medical doctor will measure patient characters [2, 3] with medical rulers or devices, such as body segment ratio, the respiratory rate, fat measurement, and face feature measured including ear, eye, nose, mouth, etc. It will take a fresh doctor a long time to grasp the criteria in Sasang constitution classification. They classify the types according to summarizing these main indexes which are the measurement results with rulers or experiences. It is a minute and complicated process with a prerequisite that the patient should come to hospital with the doctor face to face. In order to simplify the process, computer and internet are utilized. In paper [4, 5], they proposed a system to extract the front face features for Sasang constitution according to the oriental medicine. It is obvious that we couldn't catch the efficient and all information for ear feature, nose feature and proportion between them, only from the front face. They are the important information to decide the patient's type in Sasang constitution [4, 5]. In our system, we choose the remarkable features from human front face and side face. For the side face, the most representative features are the nose height and size of ear. We select the ratios between nose and ear as the standard indexes in classification.

The direction of biometrics research relies on the image analysis because of data acquired from the camera, video, sensor and mobile phone easily. These methods do not require any actions from users and the system's output is the human unique logotype automatically. The facial feature detection belongs to the physiological biometrics method [6]. In our design, system detects the feature through images, which taken by putting the user's face in front of the camera, or sensor. Our system structure is shown in Figure 1. The image is collected by user's mobile phone, and transferred by Wideband CDMA (Code Division Multiple Access).

The contribution of this paper is summarized in the following:

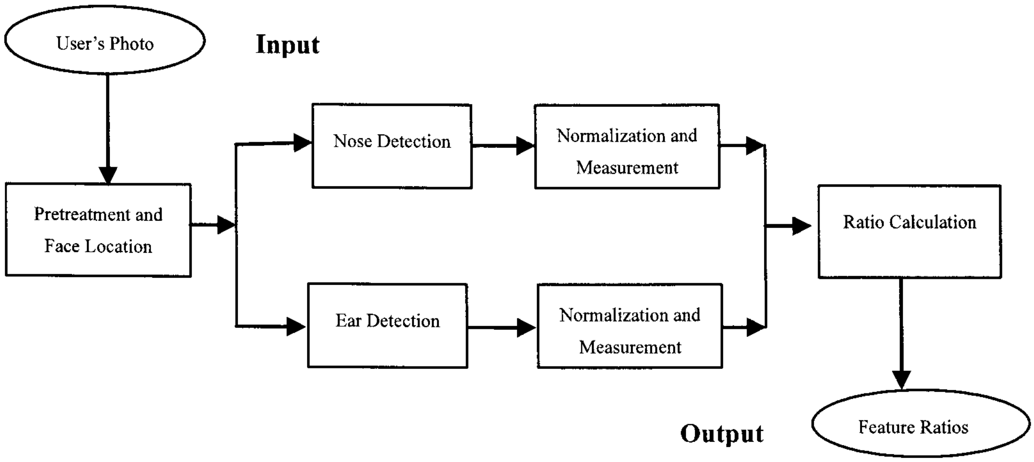
First, we propose a novel approach to detect a nose and nose's left ala in the side face image. These special feature detection are necessary in our system.

Second, we utilize a new method to detect ear from side face image. The method will also can be used in ear detection and ear recognition system. An energy formula is designed for the ear location. This is a simple and an efficient method.

Third, we design several crucial ratios as face features according to the oriental medicine Sasang constitution theory. Table 1 shows these features.

Fourth, we propose a novel method for analyzing the error caused by pose variation. Error analysis is derived based on the hypothesis that human face is nearly a sphere.

Fifth, we combine the two features from the side face with other features from the front face, and we increase the accuracy of Sasang constitution for classification. Experiment will be carried out to test system's performance at the end of this paper.



(Figure 1) The system structure including the main processing steps.

(Table 1) Facial measures recorded from the computerized profile facial photographs

Facial Feature	Description (units of measurement)
Nose region	
Nasal Height	Distance between the nasal tip and the basic of the nasal left ala (pixels) Figure 7
Ear region	
Ear Height	Height of normalized ear (pixels) Figure 8
Ear Width	Width of normalized ear (pixels) Figure 8
Ear Centroid	Point from the centroid of pixels in the ear binary image (pixel) Figure 8
Facial region	
F distance	Distance between ear centroid and nasal tip (pixels) Figure 10
F Ratio	Ratio between nasal height and F distance
E Ratio	Ratio between ear height and ear width

The remainder of this paper is organized as follows. In Section 2, we review the related works about the face detection theory and feature selection criterion. We describe the proposed system briefly and detect the region of interest including nose and ear from side face based on geometry model in Section 3. Feature ratios for nose and ear are calculated in Section 4. We present the experiment results and compare the error with manual measurements by doctor in Section 5. Future work and conclusion will be included in Section 6.

2. Related Works

The Sasang constitution is a traditional Korean medical typology, which was systematically theorized by I Jema (or Yi Jema or Lee Jema) in his book 'Dong-ui Susebowon' [the principle of life preservation in oriental medicine] in 1894. The authors in paper [2, 3] analyzed the shape differences of the body and the face according to Sasang constitution with certain results respectively. Considering about the ear, nose, mouth and eye on the human face based on Lohman's method [7], they find that different type has own characters. For example, nasal tip depth, nostril to nasal alar depth is deeper in So-Yang than in Tae-Eum. But for the patient, there are hundreds of features on his body and face. It is necessary to select the efficiency part among them. In system, we choose both of the front face features and the side face features. In the paper, we focus on the features of the side face. From the oriental medicine research, information about nose, ear shape and its size comes from the side face. The ratio for ear length and width is higher in Tae-Eum than in So-Eum. Nasal tip depth, nasal depth ratio is the highest in Tae-Eum. Nasion depth is deepest in So-Yang. We choose feature ratios from the side face which are shown in Table 1. The proceeding of our system is based on the image measurement.

The feature obtained based on geometric model should represent the essence which could discriminate it from other types, and it will also be of elasticity to decease the illumination, pose (out-plane rotation), in-plane rotation, and noise. Poggio and Brunelli [8] proposed the improved technique of integral projections for 35 facial geometrical features measured by European distance. Their method was tested on the system about 90% correct recognition using these features and perfect recognition using template matching. Chung-Lin Huang and Ching-Wen Chen [9] adopted the deformable template model for contours of eye and mouth, and active contour model (snake) for the shape of eyebrows nostril and face. Their "classification accuracy is relatively high" [9], but it is a little hard to find the proper curve to fit special shape, such as the nose shape in profile face. There are other types of theories for feature exaction according to the features' arrangement in the frontal face, such as bottom-up approach [10], top-down search [11], and some combination both methods [12]. In our system it does not work because the target lies in the side face. In this paper, we mainly adopt the technique of integral projection to detect the nose in the side face. For the ear detection from the side face, we design an energy formula to locate it in the binary image.

3. Feature Biometrics from The Profile Face

In this paper, we design and complete a system to extract feature ratios from the left side face for classification, which will be used in medicine treatment. Our feature detection algorithm is based on the geometrical model, and the system is carried out automatically without any intervention from user.

3.1 System design

Two ratios will be mentioned in the following section: the side face feature ratio (we called this F ratio in Table 1) and the ear dimension ratio (we called this E ratio in Table 1). For the F ratio, first we define two distances in the digital photograph. One is the distance between the nasal tip and the ear centroid, which is the centroid of ear binary image; the other is the nasal height. Then we use the ratio between the two distances as the human side face characteristic. The E ratio comes from the measurement of the ear width and ear length.

Our system is carried out as follows in Figure 1:

Step 1 : Pretreatment and the side face localization, which includes image denoise, image smoothing, and side face localization using the adaptive color model.

Step 2 : Nose and ear localization, normalization, and measurement.

Step 3 : Compute the F ratio and the E ratio.

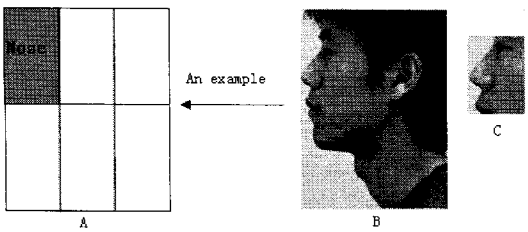
3.2 Side face detection

Face localization is the preliminary step whatever in recognition or biometrics system. In the paper, we design the adaptive color model as our solution. As we know, TL plane in TSL color space [13] is the best plane for highlight analysis, considering the color distributing shape and lightness dynamic [13].

In our system, we choose the TSL color space not YCbCr color space [4, 5] to describe the side face image. We assume that the face region located in the center of the photo because the image is taken by mobile phone and user usually tended to set his/her face in the center of the photo. The center pixels will be used to match color with all pixels in the photo through Mahalanobis Distance. Then the face region will be detected after labeling the detected region.

3.2.1 Nose feature detection and measurement

In this part, we major in the nose detection from the side face region. Nose lies in the specific area of our face, according to the human's biological characteristics. It locates in middle of the eye and mouse from the frontal human face, and on the left of the most from the left side face. In our system, the result of face region detected using the color model includes both face region and neck region. We select some special area (erase the hair part above) as the region of interest. The segment method is shown in Figure 2. Part A shows the diagram for the segment region of interest on the photograph. An example is shown as the illustration on part B and C. In the following, we will detect the nose region in Figure 2.C.



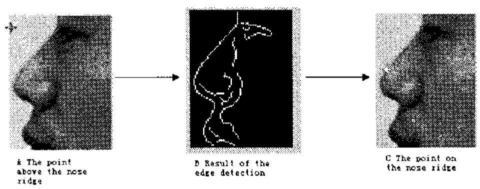
(Figure 2) Locate the possible nose region

Step 1 : Find the crucial points on the nose ridge.

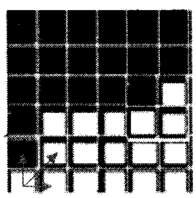
We can find a concave point at the end of the nose ridge. It is helpful for us to find the nose ridge points using the technique of integral projections [14]. The point above the nose ridge will be found first. Canny operator is better for white noise and it will be used for edge detail detection in the image. We use the canny operator to detect the edge in image. The first point on the nose ridge is located in our system. The process is shown in Figure 3.

Step 2 : Detect the nose region.

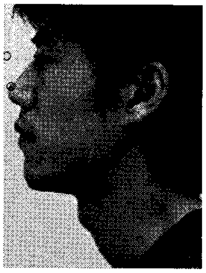
In this part, we propose the edge tracking algorithm for nose contour detection. The method is used in two directions both upward and downward. We turn the grayscale image into the binary image using Otsu's method [15]. When we use the pixel 8-neighbor hood for searching, in the upward edge tracking, there are three directions which shown in Figure 4. We search along the nasal ridge from upper, right upper and right-hand direction sequentially. Considering the gradient variation of the points on the nose ridge, we can find the nose ridge along upward direction. The same with downward edge tracking, we locate the nose tip. The result is shown in Figure 5.



(Figure 3) The crucial point on the nose ridge



(Figure 4) The three directions in upward edge tracking.

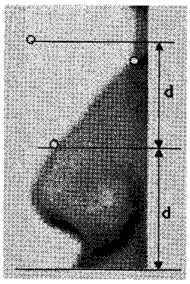


(Figure 5) Downward and Upward edge tracking results.

When we find the two crucial points, we segment the nose from the possible region. In the paper, we expand the region composed of two crucial points by twice of the length. The process is shown in Figure 6 in which d is the pixel vertical distance between the two points.

Step 3 : Locate the left ala on the left side face.

We locate the left ala, which lies in the nose area, and measure the nasal height correctly.



(Figure 6) The nose region

Then we analyze the gray value's statistical characteristic for the pixels in the nose area in the grayscale image. We observe that there are three special parts on the nose: the outer skin points, the nostril points, and the nasal ala points. The whole pixels of the nose are approximated by Gaussian distribution. Suppose is the standard derivation of Gaussian distribution, and µ is the mean of Gaussian distribution. The nasal ala points lie in of the Gaussian distribution. We set a parameter K as the threshold to segment the pixels on th e ala.

$$K = \frac{N}{M} \times 2\sigma \quad (1)$$

Where, N represents the pixel number in the nose area, and M is the total number of pixels in the image including the nose region.

$$n(i,j) = \begin{cases} 1 & \mu - K < k < \mu - \sigma \\ 0 & else \end{cases} \quad (2)$$

Where, n(i,j) is the pixel in the nose image, and k is the gray value corresponding to n(i,j). The result is shown in Figure 8, and the curve is the left ala.

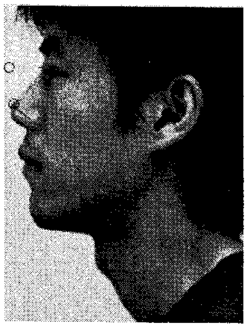
The nasal height is the distance which is measured from the nose tip to the basic of the ala according to the standard body measurement in medicine. We set the point with the highest curvature as the basic of the ala. The nasal height has been transferred into the distance between the two points. In this case, our result is shown in Figure 7.

Step 4 : Nasal Height measurement.

Euclidean distance is the ordinary way to measure the distance between two points. In our system, the nasal height is described by Euclidean distance.

$$Distance = \sqrt{(p_x - q_x)^2 + (p_y - q_y)^2} \quad (3)$$

Here, suppose the nose tip point is P =(px, py), and the ala point is Q =(qx ,qy). In this case, our result is shown in Figure 7, and the pixel distance is 97.354.



(Figure 7) The nose height described with a line.

3.2.2 Ear feature detection and measurement

Ear biometrics has been the research focus in human identification. Ear feature are relatively more stable and unchangeable from the other features on the face. In our research, we locate the centroid of the ear, and calculate the E ratio.

We detect and locate the ear on the side face image. Sometimes the ear will be hidden by several hairs. With users' help, the system could be input the side face photo including the whole clear ear.

__Step 1__ : Search for the candidate ear regions.

There are some regions which could be considered as the ear in the side face, such as the sharp hair, the headdress, real ear, etc. We choose canny operator for edge detection in the side facial photographic, as compared with other known methods such as sobel operation, prewitt operation and complex wavelets. Then we obtain the candidate areas with integral projection method.

__Step 2__ : Locate the ear with the energy formula.

In the step, we locate the ear region among the candidate regions. The shape of ear on the image is nearly like an ellipse. We propose to use the minimum energy formula for discrimination, as follows:

$$Min\ \ G = \alpha(\sum \frac{\partial^2 y}{\partial x^2})^2 + \beta(\sum \frac{\partial y}{\partial x})^2 \quad (4)$$

Where, β and α describe the shape of the ear, and α+β=1. We select that α=0.95, and β=0.05 in our system. It is decided by the experience through our experiments. The minimum energy represents the ear region.

__Step 3__ : Search for the centroid

The centroid of mass is independent of the shape transformations such as translation, rotation and scale. We search for the ear centroid as the feature point because of the invariant. The ear centroid is calculated in the binary ear image. Given the binary ear image m(i,j), we define the ear centroid (I, J) as:

$$I = \frac{\sum_i \sum_j i \cdot m(i,j)}{\sum_i \sum_j m(i,j)}, \quad J = \frac{\sum_i \sum_j j \cdot m(i,j)}{\sum_i \sum_j m(i,j)} \quad (5)$$

__Step 4__ : Normalization

As we treat the ear shape in the image as an approximate ellipse, it has a little slope reference to the major axis which is perpendicular to the horizontal direction. Sometimes error is caused by the influence of head pose. It is important to obtain the invariant about ear for biometrics correctly.

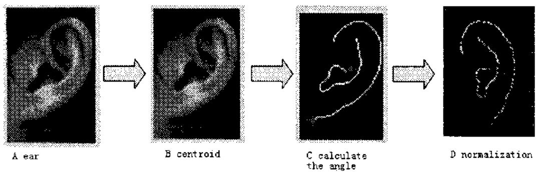
When we detect the geometry feature in the image, the experiment results rely on the quality of the photograph. The points on the top of the ear outline will be hidden by tiny fair. There are two reliable points on the image which we could detect them generally. One is the centroid, and the other is the further point apart from the centroid which lies in the earlobe contour nearby. We compute the slop of angle using the two points and translate the ear for normalization. The process shows in Figure 8. Part A is the ear region; the point '*' in part B is the centroid of the ear; we evaluate the angle in part C; and part D is the ear after rotated. The rotated angle is shows in Figure 9 and α is calculate according to the formula:

$$\alpha = \arctan \frac{y_{further} - y_{centroid}}{x_{further} - x_{centroid}} \tag{6}$$

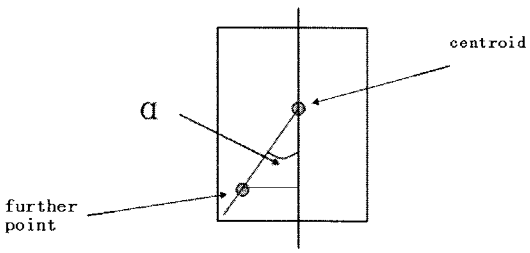
Where: the centroid is S (xcentroid, ycentroid), and the further point is T (xfurther, yfurther).

Step 5 : Ear measurement

After normalization, we continue measuring the height and width of ear with Euclidean distance.



(Figure 8) The process for ear normalization.



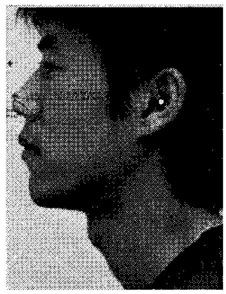
(Figure 9) Calculate the rotated angle.

4. Calculate Ratios

4.1 Calculate the F ratio

Nose and ear are the noticeable parts in the human side face. Ear biometrics has developed besides the iris, fingerprints, and face recognition. In the oriental medicine, the type of human is decided by these features. The ratio from the side face could describe the character as one of the references for oriental medical. The ratio is shown in Figure 10.

$$F \ \ Ratio = \frac{D_{TE}}{D_H} \times 100\% \tag{7}$$



(Figure 10) The measurement result.

4.2 Calculate the E ratio

It is senseless to measure the size of ear based on the image. In our system, we use the E ratio as one of the ear features.

$$E \ \ Ratio = \frac{Height}{Width} \times 100\% \tag{8}$$

5. Experiment Results and Error Analysis

5.1 Experiment results

The system was tested in our own database including 173 Korea people left side face photos. The size of test image is 1728 by 1152.

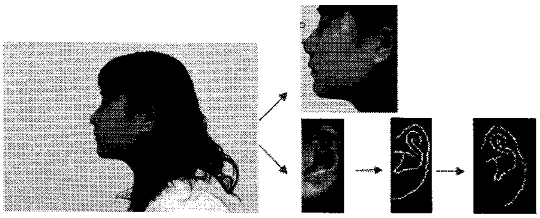
We use the universal evaluation criteria for system test. Accuracy=1-(Error_Numbers/ Total_ Numbers)*100%. Where, Error_Number is the number of wrong test result, including some situations in the system:

1. Non-face region as the result.
2. Wrong nose or ear region, such as non-nose or non-ear region, part nose or ear region detected.
3. Frustrate measurement results which is not fulfilled requirement in Medicine, such as pose strong influence, image quality, wrong crucial points.

Our system accuracy is shown in Table 2 in the following. We show another experiment results in Figure 11.

(Table 2) System test results

Test item	Side face detection	Nose region detection	Nose height detection	Ear region detection	Ear ratio detection
Accuracy	93.64% (162/173)	91.33% (158/173)	81.50% (141/173)	87.29% (151/173)	76.30% (132/173)



(Figure 11) The other results in the experiment.

In our system, through increasing the number of features, we examine the accuracy for human type classification. Here, each person type is decided by summarizing each feature's type reference to the doctor's indexes. For example, Table 3 in the following shows the nose and mouth ratio used for classification. First, we select seven features from human front face about the ratio for width of nose bridge, width of mouth, distance of two eye pupil, width of two nose alas, width of two eyebrows and so on. Compared with the doctors decision in the database, there are 7 person's type which couldn't be decided among 173 people, and the accuracy of our system only is 64.67%(108/167). Then, we add the two ratios from the human side face into feature space. We have nine features for human type classification. Our system can deal with all persons' type in the database, and the accuracy turned into 82.66%(143/173) which is increased 17.99%. The result shows that the more features can enhance the efficiency of classification.

(Table 3) The ratio between mouth width and nose bridge width for classification

Range (ratio)	Type
$x \leq 139.7$	So-Yang
$139.7 < x \leq 155.32$	So-Eum, So-Yang
$155.32 < x \leq 156.12$	So-Yang
$156.12 < x \leq 156.76$	So-Yang, Tae-Eum
$x > 156.76$	Tae-Eum

5.2 Error Analysis

5.2.1 Feasibility study on feature ratio

Due to the optical properties of camera lenses, the object measurement result will vary with the change of object distance. It is not suitable to choose the pixel distance as our results obviously. But the ratio between the two pixel distances will be the invariant. It provides the probability to choose ratio as the feature.

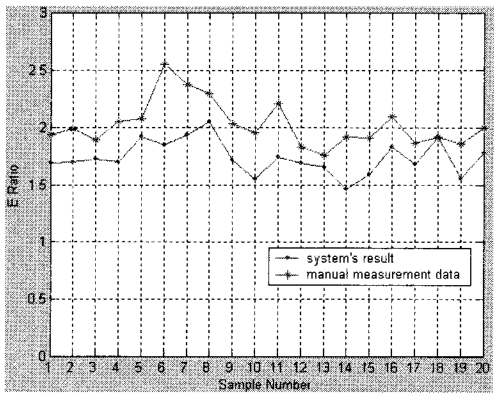
We analyze the results comparison to the manual measurement data. Doctor obtains the feature data using the special tool directly and normalizes the unmeasured human ear by experience. In our system, we rotated the ear region for normalization. We change the original position of ear. Normalization is very important for computer measurement because of the influence of the pose and illumination. There always exists difference between the doctor's results and the computer's output. Figure 12 shows the difference. We selected 20 tested results stochastically as our samples. The lines in the figure are the manual measurement data, and the system's results. From the figure, we could find that the manual result is always larger than the computer's result, because the ear width would be larger as we rotated for normalization (the difference relies on the ear shape). The data measured by computer will be used for classification. The special sample such as No.6, there is completely different between the system's result and doctor's data. The error is caused by the ear shape shown in figure 14.

5.2.2 Influence of pose for head rotation

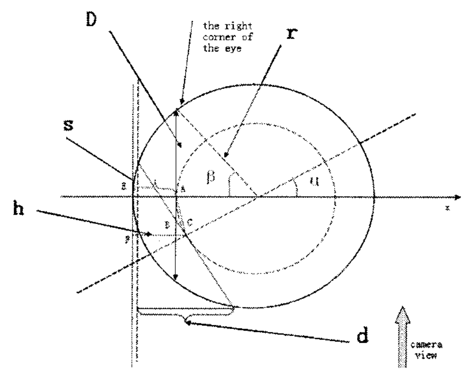
When we use the computer to detect and measure human body, we should consider the influence of the head pose. The result changes with the change of the head pose. In our system, as the head rotated in-plane upward or downward it has no influence on our result. But it would change our result as the head rotated out-plane inside or outside. It is necessary to analyze the influence caused by the head rotation.

We only care about the error caused by the head rotation without considering the actual measurement result. The nose measurement is similar with ear. The influence for nose is the height error, and for ear is the width error. We focus on analysis the nose measurement error. Suppose the head is a sphere, and figure 13 shows the hypotheses of the head feature. We observe the head from the top of head to bottom; x-axis represents the plane, and α means the angle of the head rotation. In the figure, we suppose s is the actual height of the nose, h is the measurement for the nasal height, r is the radius of the virtual human brain, D is the distance between two eyes, and d is the measurement distance between two eyes from the side face.

Our detection algorithms to find the nose tip according to the edge tracking. When the head rotates out-plane, the approach detect the further points on the nose which means the "nose tip".If the angle is very large, the nose tip maybe will be the skin on the face. The error is the distance between point B and C in the figure 13, where the arrow lower right-hand corner is the camera view.



(Figure 12) The difference in the E ratio between manual measurement data and system's result.



(Figure 13) Error analysis is shown.

$$
\begin{aligned}
Error &= d_{ac} * \sin\frac{\alpha}{2} \\
&= 2 * (\frac{1}{2} D^* ctan\beta^* \sin\frac{\alpha}{2}) * \sin\frac{\alpha}{2} \\
&= D^* ctan\beta * \sin^2\frac{\alpha}{2} \\
&= D^* ctan\beta * \frac{1-\cos\alpha}{2} \\
&= k \times \frac{1-\cos\alpha}{2}
\end{aligned} \quad (9)
$$

Where, k is the constant coefficient, and the error is caused by the angle of rotation. When the head rotates in the opposite direction which means α less than 0, error is less than 0. The same process occurs with the case above.

For example, suppose the input image is 1728*1152. The distance between the two eye's corner D is 230 pixel, β=30º. If the error equals to 1 pixel, the angle of rotation will be 6º. If users pay attention to the problem, and keep the head being nearly the standard profile, the error could be ignored.

6. Conclusion and Future Work

In the paper, we introduce our system for biometric in the human side face. The face detection from the background is the first and crucial step. We applied the adaptive color model for the problem. There are other two important parts, nose detection and ear detection from the digital photograph. The detection method is mainly based on the geometry model. At last, we compare the error with the manual measurement data. Our system is an efficient and accurate way which will be used in the tele-health system.

There are some problems in the system. The test results are mainly decided by the quality of the photograph. Adaptive color model is the perfect way to detect face, but it is influenced by the light and background color sometimes. In our system, it is necessary to put the side face in the center of the photo, which is solved by the mobile phone camera. The hair, especial the man's tiny hair will hide the little part of the ear, which will cause error for our result.

The modes for feature detection and the measurement will also be applied in many fields, such as object classification, human body measurement, the human race research, facelift, etc. In the future, we will improve our system further. As we detect the feature, we will continue research for the classification of human people depending on data mining methods, such as Support Vector Machines, Artificial Neural Network, etc.

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