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A physiognomy based method for facial feature extraction and recognition

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ABSTRACT

This paper proposes a novel calculation method of personality based on Chinese physiognomy. The proposed solution combines ancient and modern physiognomy to understand the relationship between personality and facial features and to model a baseline to shape facial features. We compute a histogram of image by searching for threshold values to create a binary image in an adaptive way. The two-pass connected component method indicates the feature's region. We encode the binary image to remove the noise point, so that the new connected image can provide a better result. According to our analysis of contours, we can locate facial features and classify them by means of a calculation method. The number of clusters is decided by a model and the facial feature contours are classified by using the k-means method. The validity of our method was tested on a face database and demonstrated by a comparative experiment.

1. Introduction

The physiognomy phenomenon had been a part of Chinese culture since ancient times. To a certain extent, it has had a profound impact on China's political, economic, cultural and daily life [2,3]. In ancient times, this visiting fortune-teller custom was popular with upper officials belonging to the "official school" and it appeared in the neighborhoods of the west and east Han Dynasties, then spread exponentially [13,14,16–18]. Fig. 1 shows the traditional physiognomy. Facial features have been considered in terms of evaluating a person's disposition for thousands of years in both eastern and western cultures. With the development of big data, computer visualization and image processing, more and more statistical data are used to provide facts. Statistical results have verified that there is a strong connection between facial structures and personality traits. For now, various vocational institutes, such as the Merton Institute, which provides services to such companies as AT&T, have used physiognomy as one of their main tools in assessing candidates [1,2,4,6]. A psychological research of Israelis shows that about 75% believe in physiognomy, whereas only 25% think that physiognomy is impossible (the sampling error of the survey is 4%) [3]. Aristotle in his famous work prior analytics asserted, "*It is possible to infer character from features, if it is granted that the body and the soul are changed together by the natural affections*" [39]. It has been verified that people with similar facial features exhibit similar behavioral patterns. A novel practical personality analysis system has been presented by Hsu et al. in 2013 [28] which integrates the professional psychometric personality test with the designed shape-based facial features. In the literature, they construct a personality database by inviting a number of volunteers to fill a questionnaire and they employ a clustering method to classify each facial element from the training set and to verify the connection between facial features and personality. However, the process of extracting and defining facial features and identifying the number of clusters is challenging since it is very difficult to define personality.

In this paper, we propose a new calculation method of personality according to physiognomy. We summarize facial feature classification based on physiognomy. Based on this classification, we design a method to extract facial feature points to help us compute the size of facial features and we employ a number of specific facial features to decide on the number of clusters in particular cases. First of all, we cumulate the histogram of each image and find the better threshold value by using the method of Otsu which is an adaptive method [19]. By using this method we can generate a quality binary image. Then the connected component is used to find the boundary of each facial feature in the face image. We save the contour sequence of the facial feature and locate each facial feature. Third, the classification is decided by two methods.

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Fig. 1. Physiognomy image [13].

The first is the calculation method we have proposed and the other is the clustering method. Comparing the results of the two classification methods, the validity of the calculation method is verified in a very explicit way. This paper is extended from its conference version [29].

2. Related work

Many people in the world history have used the face reading tactics to know others. They all attempt to summarize the experience of facial feature and firmly believe that the face tells a story of one's life. The initial studies were followed by Secord's seminal and comprehensive work before 1970s [30–33] and then research with a focus on baby faces [34]. Psychologists have done much research on face's inner meaning for a long time and showed that different faces reveal different personalities [12,15]. In spite of much research of face reading, it was confusing to researchers that psychological meanings for the same facial feature could be opposite in different papers. So Barbara [2] in clinical medical research (UCSD) proposed to develop an accurate system of psychological meanings which would reflect different levels of all ethnic groups, ages and genders. He studied 6000 faces, proposed accurate and specific psychological meanings for each facial feature which were displayed in many activities. It turns out that people have validated the psychological meaning to be accurate for understanding people.

In China, the ancient people had a great esteem for physiognomy. In the beginning, this kind of fortune-teller custom was popular among the upper officials. For political needs, some dynasties had even created positions for fortune-tellers. The face reading was mainly used to choose officers as well as select concubines because of the feudal rulers deeply convinced by physiognomy. Since Han Dynasty, physiognomy appeared in the folk quietly and then spread like floods. The phase of people asking for was related to every aspect of life, such as health, longevity, love marriage, fortune, career, academic and so on [13,14,16–18]. To some extent, therefore, face reading had an impact on the ancient Chinese political, economy, military, culture, medicine [7–11] and other aspects. Then as the country gradually became open to the rest of the world, a large number of western reading methods were introduced into China and integrated with traditional Chinese physiognomy, which produced the New Face Reading [29]. The purpose of New Face Reading is to determine a person's character suitable for what kind of occupation, rather than his/her fate by observing appearance. However, until now, physiognomy belongs to the non-mainstream borderline culture in today's society. And people who do not have rational knowledge of physiognomy tend to think of it as a kind of superstition and neglect the social cultural function of physiognomy.

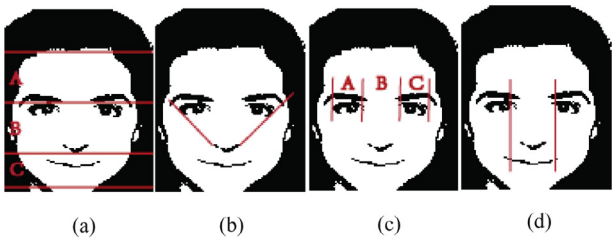

Fig. 2. (a) Face classification standard (b) eyebrow classification standard, (c) eye classification standard, (d) mouth classification standard.

With the increasingly fierce competition in the market today, employment has become a top priority of the contemporary university graduates. In fact, for recruiters, how to choose high-quality staff among candidates is not easy. Before the first meeting between a recruiter and a candidate, the understanding of the candidate is confined to the text on the resume. As a result, the first impression is very important, which is known as "the first effect". As a result, many researchers have built models to select talents by using physiognomy as a main tool. Zebrowitz and Collins [5] reviewed Gibsonian ecological approach and Brunswik's lens model [5] and elaborated a developmental model of relationships between physical and psychological qualities. That model highlights the need of research in identifying configurable physical qualities that may inform accurate perceptions. However, little progress has been made in this regard. Hsu et al. [28] proposed a novel practical personality analysis system based on facial features reading which called "Physiognomy Master". They constructed a new big database of facial features' values and investigated the professional personality of volunteers to find out possible relationships between facial features and personality traits. Based on the perception that people with similar facial features possess similar personality characteristics, they proposed a fusing mechanism that was a powerful tool in social interactions and has achieved positive results.

3. Facial features classification based on physiognomy

The ancient researchers of physiognomy studied countless faces over a long period to determine face reading rules. Physiognomy is one of the most intuitive methods to reflect a person's personality. We have combined ancient and modern physiognomy to understand relationships between personality and facial features.

3.1. Face-shape classification standard

According to the theory of the "San Ting" [13], the person's face is divided into three regions, which are shown in Fig. 2(a).

The face shown in Fig. 2(a) includes three parts, which are A, B, C. The A part is from the top of the head to the middle of the eyebrows and eyes; The B part is from the middle of eyebrows and eyes to the end of the nose; The C part includes the philtrum, mouth and chin areas. We decide the face-shape on the basis of the ratio of these three parts.

A zone is on the top part of the face, which is associated with the brain. It is related to people's cognitive activities, judgment and intelligence.

B zone is the reaction area of human emotion, which is related to people's feelings and social skills.

C zone has a very close relationship with the mouth, which can reflect one's activeness and vigor. There is no denying that some singers and athletes may have better developed this area.

Basically, face-shape can be divided into seven categories according to the three different regions which are: the oval face, round face, nabla face, equilateral triangle face, long face, square face and diamond face.

(1) *Oval face*: B is developed and the face is narrow. Most of women with oval faces are said to be beautiful and compliant. They can also juggle work and family. Oval faced people are thought to be rational, emotionally stable and creative. They possess a very high self-esteem but they may lack stamina.
(2) *Round face*: B is relatively developed and the face is wide. People with this kind of face shape are relatively fat. These people are mild, warm, friendly and have very good coordination, but they can be very capricious and individualistic. Men with round faces may understand how to refuse others and they can be duplicitous.
(3) *Nabla face*: The area A is wide, B and C are narrow. This kind of face is small and the bodies of people with this face type are also small. Most of these people are clean, meticulous, cold and anxious. These people are also indecisive. They are focused but too confident.
(4) *Equilateral triangle face*: The area of C is wide. The overall face is angular, the forehead is small and the cheekbones are big. These people are stubborn, indomitable, nervous, vain and fearful of power. These people work actively, and usually get along well with like-minded people.
(5) *Long face*: Three areas of the face have the same width. People with this kind of face are careful, studious and good at communicating with others. They seem reasonable at first glance, but they find it hard to be themselves in front of people. Most males with this face shape are playboys, but females are very shy.
(6) *Square face*: Like the long face, the width of three areas is the same, but wider. Such people show a positive attitude to everything. Their willpower is strong. They are spirited and have a sense of justice, but they are lacking in terms of accommodation.
(7) *Diamond face*: The parts of A and B are the same, but C is relatively narrow. These people are very keen to study, patient, thoughtful and have compassion. The boy of this face-shape is single-minded, but the girl is just the opposite.

3.2. Eyebrow-shape classification standard

The length of the eyebrows is benchmarked against the extended lines, which are from both sides of the nose to the canthus. Fig. 2(b) shows the benchmark.

According to the two baselines, brows can be divided into four categories: eyebrows front on the baseline, eyebrows front beyond the baseline, eyebrows front inside the baseline, eyebrows front-end upward deviating from the baseline.

(1) *On the baseline:* This kind of eyebrow is an ideal eyebrow. These people are passionate and loving.
(2) *Beyond the baseline:* People with this kind of long eyebrow are gentle, tolerant and slow to anger.
(3) *Inside the baseline:* These people are always kindhearted, honest and they work hard.
(4) *Upward:* People who have the upward eyebrow with a straight edge are nice and easy going.

3.3. Eye-shape classification standard

We define the distance between the eyes as a benchmark. As shown in Fig. 2(c), we have 3 parts which are part A, part B and part C. Parts A and C are the eyes of a person, and the width of them are almost same. We compare the width between A and B to decide whether the eye is big or small.

(1) *Small eyes:* The size of the A area is smaller than the B area. People with small eyes are usually strong in terms of endurance, dependable and careful. Girls are usually moody.
(2) *Big eyes:* The size of the A area is bigger than the B area. The curiosity of these people is strong and they are expressive. They may be enthusiastic, pushy, and like colorful things. They possess a mixture of self-esteem and vanity.

3.4. Nose-shape classification standard

The length of the nose is based on a third of the total length from the hairline to the chin. We call it a big nose if the length of the nose is bigger than the benchmark. And the height of the nose is based on the half of the nose length. It is a high nose if the size of the height is bigger than the benchmark. According to the width and the height of the nose we divide the nose into seven categories: the Greek nose, short nose, seg nose, bag nose, straight nose, hawk nose and fault nose.

3.5. Mouth-shape classification standard

The mouth has size and the lips have thickness. Here we just talk about the size of the mouth. As shown in Fig. 2(d) we draw two straight lines from the inside point of the iris to consider the size of the mouth. Usually, the length of the girl's mouth is 4 cm and the boy's is about 4.6 cm.

(1) *Big mouth:* The corner of the mouth is outside the line. These people are energetic and aggressive.
(2) *Small mouth:* The corner of the mouth is inside the line. People with small mouths are unenthusiastic, implicative and do not know how to refuse others' opinions and demands.

The above are statements of the calculation and classification method of facial features based on Chinese physiognomy.

4. Unsupervised facial features extraction

Throughout the whole human history, people share the belief that the face can reveal innate traits of a person. This has motivated us to explore the scientific value between personality and innate traits of a person. To achieve this, we first need to find a way of extracting facial features. Facial analysis is an area that has been researched extensively in computer vision, psychology and human-computer interaction, while facial features extraction is still at its initial stage of research. Usually, there are two types of facial feature extraction methods: texture-based and shape-based methods and the latter method is closer to the human thinking.

According to the facial feature classification we have introduced in the last section, we need to extract the key points which can be defined as the endpoints of each facial feature to divide the facial areas and classify facial features. In our paper, the most significant feature points are eye corners, mouth tip and mouth corners which are the key locations for face feature classification. Algorithms that can quickly extract the facial feature points have been developed based on histogram representing cumulative distribution function scheme [23,24]. Accordingly, we use the following steps to find out these key points. First of all, the histogram of each image is computed and an adaptive threshold value method, the Otsu method

[20], is used to get the binary image [19]. Then the connected component of the binary image is indicated on our respective feature region and the connected domain is marked at the same time to help find the feature region easily [26,27]. According to our experience, a simple research method is applied to define the sequence of the connected domain and to extract the key points that we need.

4.1. Image binarization

The image binarization is the initial stage for facial features extraction. To create the binary images, the following mathematical concepts are applied on original images.

$$Hist(grayL) = \sum_{i=0}^{H}\sum_{j=0}^{W} P_{I(i,j)} \tag{1}$$

$$P_{I(i,j)=}\begin{cases} 1 & when \quad P_{I(i,j)} = grayL \\ 0 & otherwise \end{cases} \tag{2}$$

$$I_b(x,y) = \begin{cases} 255 & when \quad Hist(v) <= Th \\ 0 & otherwise \end{cases} \tag{3}$$

Where $I(x, y)$ is denoted by original gray scale images, $P_{I(i, j)}$ is the histogram representing the time of an occurrence of a pixel of gray level grayL, H is the height of image, W is the width of image, Hist(grayL) is the cumulative histogram function up to the gray level grayL for an image $I(x, y)$ [21,22], where $0 \leq$ gray $L \leq 255$. The new binary images, $I_b(x, y)$ is achieved when $Hist(v)$ value does not exceed the threshold value Th and the $I_b(x, y)$ image only contains the black pixels of the facial feature of the connected component area.

The threshold Th is determined by the Otsu method which is an adaptive method [19,20]. The work is described in the following equations.

$$g = w0 * (u0 - u)^2 + w1 * (u1 - u)^2 \tag{4}$$

$$u = w0 * u0 + w1 * u1 \tag{5}$$

Where w0 is the proportion of the number of foreground pixel points accounting for the total number of the image, u0 is the average value of the number of foreground pixel points, w1 is the proportion of the number of background pixel points accounting for the total number, u1 is the average value of the number of background pixel points, and u is the total average gray level of the image. The final picture of the binary image is shown in Fig. 3. This method easily finds a relative threshold to achieve a nice binary image.

4.2. Connected component

In the binary images we can see that the black parts are the facial features we need in connected areas.

In the image processing the connected component analysis is the commonly used method of image area (Blob) extraction. Two common connectivity analysis algorithms are the two-pass method and the seed-filling method. Generally, connected regions refer to the image with the same pixel value and the position of the prospect of the adjacent pixels image region. Connected Component Analysis refers to identifying and tagging the connected areas of the image [25–27]. Using a contour technique to detect and label both internal and external contours of each component is the main step. In this paper, we use the two-pass method to find out the connected areas of the binary image:

We note b(x,y) as the pixel of the binary image. Further, we makes foreground pixels value equal to 1, background pixels value equal to 0, and label be counted from 2. And we use the algorithm of 4 - neighborhood. The two-pass method needs to scan the image twice.

Fig. 3. Binary image.

Fig. 4. Connected images.

(1) *First pass*: reading the current pixel B (x, y), if B (x, y) == 1: if all pixels of b(x,y)-neighborhood are 0 then value b(x,y) a new label, Label = Label + 1; else b(x,y) = min{Neighbors} and record each label in neighbors.
(2) *Second pass*: reading the current pixel B (x, y), if B (x, y) > 1, find the minimum label value among values which belong to the equal relationship and give it to b(x,y); After the second scanning, the image pixels are formed with the same connected areas.

The results of the connected component images are shown in Fig. 4. It is easy to find each facial feature of hairline, eyebrows, eyes, nose and mouth. However, there are some interfering factors, such as the hair, discrete points and so on. And also we erode the binary image to remove the noise points and get new connected images which are shown in Fig. 5.

Now that we have achieved the feature sequences of each facial feature, the next step is to define the sequences and decide the location of each facial feature.

4.3. Facial feature location

The connected areas have been stored in sequences and we can see that in Fig. 6. According to the method before, we can divide the internal and external contours of each component clearly. It

Fig. 5. New connected images.

Fig. 6. 'c' and 'h' contours.

can be seen that face contour is the only external contour and other contours are internal ones; this will help us find out key points of facial features. These sequences are labeled c or h, where 'c' stands for 'contour', while 'h' stands for 'hole'. Some of contours which are labeled 'c' represent exterior boundaries of regions and the other contours represent interior boundaries. In this figure, the green lines show the 'c' and yellow lines show the 'h'. And most of the green lines are the face outline and hair. The yellow lines can be defined as eye, nose or mouth.

After the connected component analyzing, locating the facial feature is necessary. We analyze the sequences of connected component and summarize the characteristics of facial features, a simple linear and area concept is applied on connected images to detect the feature point locations:

- The max sequence of connected components where the number of points is greater than 2000 is the outline of the face. And we denote the hairline as the first line and the chin line as the end line in the sequence. The left end point and right end point are used to calculate the width of the face.
- Starting from the top-left contour position for the left and right points of the left eyebrow and eye. The search ranges from the top to a third of the height of the face.
- Continue scanning after the so called eye area, and the left and right corner points of the nose will be located. The nose area is below the eye area and almost at the center of the face.
- Starting from the bottom contour position for the mouth corner points.

The employment of prior knowledge and the linear searching method help us to find the position of each facial feature and get rid of noises of the face. The results are shown in Figs. 7 and 8. It is clear that the specific facial features have been located. The located contour corner pixel positions are the corner points we need for classifying the facial features and matching the personality. This method reduces the data dimension, the number of facial feature points and improves the classification speed effectively.

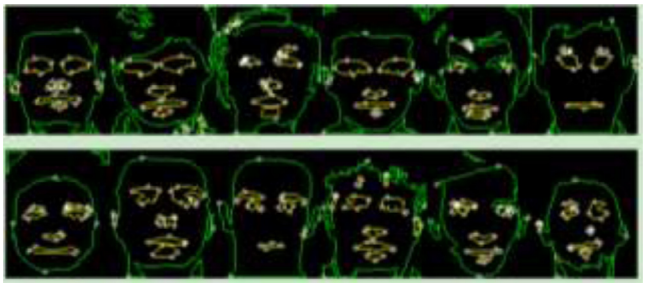

Fig. 7. Endpoints of each facial feature.

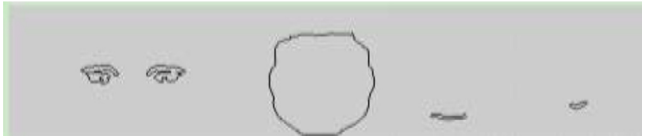

Fig. 8. Feature contour.

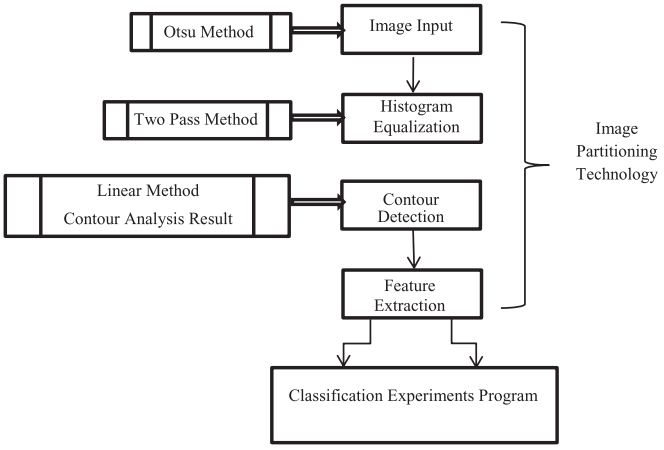

Fig. 9. The processing of facial feature extraction.

Fig. 9 presents the functional flow of the image processing of the feature extraction strategy as we have described in the this section.

5. Experiments of facial feature classification

We conducted an experiment to compare two different methods: K-means clustering method [38] and Chinese physiognomy classification method. The experiment was on facial feature sequences to classify the face-shape, eye-shape and mouth-shape. We present the details of the experiment in this section.

5.1. K-means clustering

K-means is an iterative algorithm and it attempts to find the natural clusters in the data. We need to set the desired number of clusters and then K-means rapidly finds a good placement for the cluster centers. A good placement means that the center of the clusters tends to end up being located in the middle of the natural clusters.

In this study, the number of clusters has been set as the same number of the facial shape classification that we have summarized before. The number of face clusters is 7 and the number of eye and mouth center clusters is the same being 2. The process runs as follows.

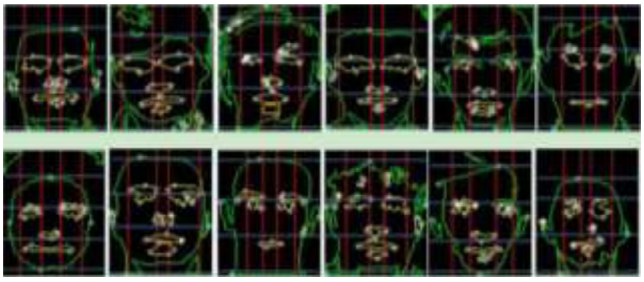

Fig. 10. Facial feature classification standard lines.

- Input facial feature sequence as data set and number of clusters K(chosen by classification)
- Randomly assign cluster center locations.
- Put each point into its nearest cluster center.
- Change the center points to the real center point of the new point set.
- Return to step 3 until convergence(cluster centers do not move again)

K-means does not guarantee to find the best result, so we run the K-means method several times with different placement of the cluster centers and choose the best run whose results have the least variance.

5.2. Chinese physiognomy classification

The facial feature will be classified by using the facial feature classification standard that we have summarized previously.

First of all, the endpoints of each of the facial features sequences have been signed. We draw four transverse lines as the standard of face outline classification. The first line is at the top point on the face outline and the last one is at the bottom. It is located above the eyes' top point as the second line of the face. And the third line is under the bottom point of the nose sequence. In order to ensure the accuracy of the results, if the nose sequence has not been found, the third line will be set above five pixels of the top point of the mouth outline. The combination of the height of standard lines and the width of the face is to make sure the face class.

Then, four points which are the left endpoints and right endpoints of the two eyes have been chosen as a benchmark. By painting four datum vertical standard lines, the face can be divided transversely into three parts to determine the size of the eyes and mouth.

The resulting pictures are shown in Fig. 10. Human face image data in the database has a lot of noises, such as hair and beard. At the same time, some of the human face images are not very positive, and these produce shadows and reduce the accuracy of the image feature extraction. In general, when the front face is not positive, the boundary of one side eye and the face outline is fuzzy which means that the data sets we get are missing an eye on the face. But the situation will not influence the result for the facial symmetry.

5.3. Experiment results

Tables 1–3 show the comparison between the k-means cluster method and the physiognomy classification. We denote each image in the source data as *Xi* in the table in which *i* represents the number that we used to differentiate between images.

As can be seen from these three tables, the results of the eye and mouth classification are very similar, while the results for face classification are positive. This verifies that there is a connection between the statistical method and the calculation method that we summarized from physiognomy.

Table 1
Eye classification result.

Eye	X1	X3	X4	X7	X8	X9	X11	X12	X14	X15	X17
K-means	1	1	1	1	2	2	2	2	2	2	2
Physiognomy	1	1	2	2	2	1	2	1	2	2	2
	X18	X21	X22	X23	X24	X25	X28	X29			
K-means	2	1	2	2	2	2	2	2			
Physiognomy	2	1	2	2	2	2	2	2			

Table 2
Mouth classification result.

Mouth	X1	X3	X4	X7	X8	X9	X11	X12	X14	X15	X17
K-means	1	1	1	1	2	2	2	2	2	2	2
Physiognomy	1	2	2	2	2	1	2	2	1	1	2
	X18	X21	X22	X23	X24	X25	X28	X29			
K-means	2	1	2	2	2	2	2	2			
Physiognomy	2	2	2	2	2	2	2	2			

Table 3
Face classification result.

Face	X1	X3	X4	X6	X7	X8	X9	X11	X12	X13	X14
K-means	1	2	1	3	4	3	5	4	1	4	5
Physiognomy	1	2	1	3	4	3	5	4	2	4	4
	X15	X17	X18	X21	X22	X23	X25	X26	X28	X29	
K-means	6	2	4	5	5	4	7	5	5	6	
Physiognomy	6	4	2	5	5	6	7	5	2	6	

6. Conclusion and future work

In this paper, we focus on finding a standard to measure each feature of the face based on previous experience. We extract salient facial features based on the histogram method, which uses the adaptive Otsu threshold value to get binary images. Then we achieve the connected component by employing a two-pass method and obtain connected images. We optimize the connected images by eroding the binary images to remove the noise points. Then we locate four areas (left eye area, right eye area, nose area and the mouth area) by combing the linear method and the priori knowledge. The key endpoints are found after we analyze the located feature sequence which is used to divide the face region. The k-means method and the physiognomy method that we propose are compared at the experiment section of the eye, nose and face classification. The results show that the classifications are almost the same.

The future work should be devoted to the following aspects. First, human face image data in the database has a lot of noise, such as hair and beard, which reduces the accuracy of classification. So it is necessary to construct a training database of front and side static faces such as photos without makeups. This can help reveal validity and consensus that agrees with the intuition of most people. Second, it is important and impendent to enhance the accuracy of facial feature algorithms, which will help us lay a good foundation for clustering and classification. Third, the methods of clustering and classification should be improved and refined. Furthermore, we will try to use some machine learning and visualization algorithms (e.g., [35–37,40]) to classify face images and compare the consistency and show the results clearly. At last, we will use the standards we summarized and the facial feature extraction methods we developed to build a system to calculate a person's personality.

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