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Real-Time Face Avatar Creation and Warping Algorithm Using Local Mean Method and Facial Feature Point Detection

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ABSTRACT

Human face avatar is important information in nowadays, such as describing real people in virtual world. In this paper, we have presented a face avatar creation and warping algorithm by using face feature analysis method, in order to detect face feature, we utilized local mean method based on facial feature appearance and face geometric information. Then detect facial candidates by using it's character in YC_bC_r color space. Meanwhile, we also defined the rules which are based on face geometric information to limit searching range. For analyzing face feature, we used face feature points to describe their feature, and analyzed geometry relationship of these feature points to create the face avatar. Then we have carried out simulation on PC and embed mobile device such as PDA and mobile phone to evaluate efficiency of the proposed algorithm. From the simulation results, we can confirm that our proposed algorithm will have an outstanding performance and it's execution speed can also be acceptable.

Key words: Face Recognition, Avatar, Facial Feature, Local Mean Method

1. INTRODUCTION

In the research of virtual reality, user avatar is mean of the user's representative in virtual space, this particular virtual object is help to take the user from the real world to the virtual world. And nowadays, since instant messenger and chat services are frequently used in our daily communication beyond nationality and languages, emoticons and expressive avatars are widely used to provide nonverbal cues to text-only messages [1]. And research on emoticons and avatars report positive effects on computer mediated communication. Those researches indicate that emoticons and avatars improve user experiences and interactions among participation and friendliness in intercultural communication. Until now, there have been many researches about user avatars develop, but most of these researches need users to utilize the sensing equipment to transmit their gesture, locality, movements and environmental information to their avatar. And user avatar model can get data from these sensing equipments and make corresponding sculpt such as: smile, angry or any other motions [2]. Though through this method can get corresponding exact data, but with its' cost is so many expensive sensing equipments with complex sense terminals. It does not have practicality for peoples' daily life. What we need is an application than can allow people to get his or her avatar model and control the avatar model easily, not with any large and complex equipment.

Human activity is a major concern in a wide variety of applications such as video surveillance, hu-

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man computer interface, face recognition [3-5], and face image database management [6]. Detecting faces is a crucial step in these identification applications. Most face recognition algorithms assume that the face location is known. Similarly, Face tracking algorithms often assume the initial face location is known. Note that face detection can be viewed as a two-class (face versus nonface) classification problem. Therefore, some techniques developed for face recognition (e.g. holistic/template approaches [7,8], Feature-based approaches [9] and their combination) have also been used to detect faces, but they are computationally very demanding and cannot handle large variations in face images.

Various approaches to face detection utilize techniquessuch as principal component analysis, neural networks, machine learning, information theory, geometrical modeling, (deformable) template matching, Hough transform, motion extraction, and color analysis. And they can be totally divided into four categories [10]: knowledge-based methods, template-based methods, feature invariant methods, or appearance-based method. Knowledge-based methods as discussed by C.Kotropoulos and I. Pitas [11] attempt to describe all the face patterns using rules based on human knowledge such as the fact that all faces have two eyes and a mouth. Template-based methods as discussed by A. Yuille, D. Cohen, and P. Hallinan [12] represent the face class by templates with allowable deformations that rely on the alignment of feature points. Feature-invariant methods as discussed by K. Yow and R. Cipolla [13] are hard to use in detecting faces in real images as it is difficult to find features that are truly invariant with respect to all faces and large perturbations in lighting, pose, and expressions. Face analysis method based on face recognition and physiognomy is proposed by E. J. Lee [14]which is just focused on the face recognition based on facial geometry. And also this method can't make real time avatar and morphing/warping image on mobile phone as well as internet. To overcome some of the difficulties, in this paper we will present an algorithm which utilize local mean method based on appearance-based associated method and associate with knowledge-based method to detect face region and facial feature points. The proposed algorithm can be implemented on web as well as mobile phone to analyze real face. And also, the input real face and real avatar can be controlled by using proposed warping and morphing algorithm.

We carried out simulation on PC to evaluate efficiency of the proposed algorithm. From the simulation results we verified that the proposed method can be practicable to achieve face region and feature detection. And the detection rate for simple environment is near to 93.25%, and 85.65% for complex environment.

Rest part of this paper is organized as the following: chapter 2 will discuss face feature detection algorithm, and chapter 3 will complete face feature modality analysis and face avatar creation; chapter 4 will show the experiment results and finally the conclusion of this paper will be indicated in chapter 5.

2. FACE FEATURE DETECTION ALGORITHM

Usually object and simple background have a clear boundary in the histogram, as we can observed in Fig 1 (a), but with increasing of background complexity, the boundary will be more and more mixed (as seen in Fig 1 (b)), this make it difficulty to confirm the threshold value which is used to separate object from background. But as observed in Fig 1 (c), if background is segmented into small pieces but enough to contain an object, in each piece of the region, the background is similarly like simple. In this case, boundary between object and background can be see clearly in its' histogram. And mean method can be employed in

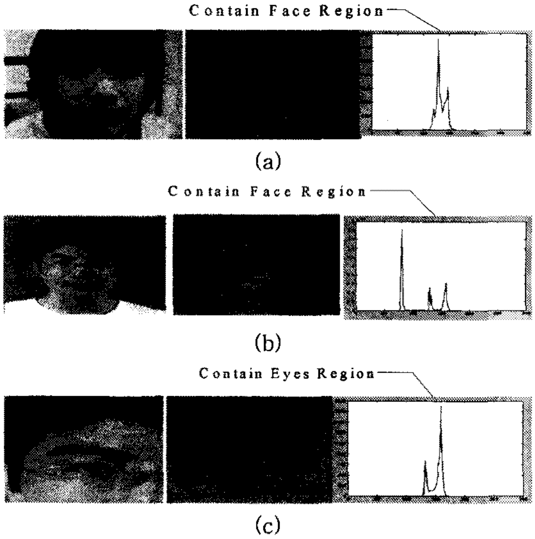


Fig. 1. Object in Different Background (where the first image is source image; second is Cr sub-color image of source image and third is histogram of Cr gray value): (a). Simple Background; (b). Complex Background and (c). Object in Small Separated Background.

this small piece region to confirm the boundary value. Thus object can be exactly extracted from background. Processing of this method is very like a pyramid approach as seen in Fig 2, firstly find several independent objects in the whole image,

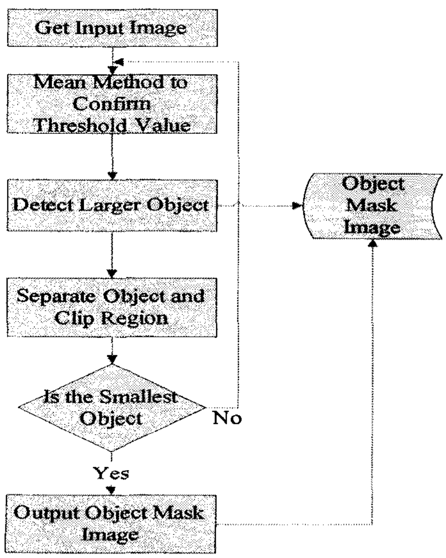


Fig. 2. Algorithm Processing Modeling

and next find the small objects in each object region, until the smallest object which be needed is found. It is especially outstanding for finding small objects such as: eyes, nose or mouth.

But for an object, we must roughly know which region it is in and decrease the searching scope. That is based on the knowledge which can not be changed. Then we can make rule to search objects. For human face, as we can know that, if it is captured from front view, eyes is always on the top of mouth, and left eye on left side of face, right eye on right, nose is always between eyes and mouth in vertical direction. We can consider these as a rule and make it more clearly as the following:

a) Mouth, eyes, eyebrows and nose are always inside of face region.
b) Left eye is on left side of face and right eye is on right side of face.
C) Distance between left eyebrow and left eye is the least than distance between left eyebrow and other facial feature. Also distance between right eyebrow and right eye is the least.
d) Nose is always between eyes and mouth in vertical direction.

According to the rule, and associate with facial appearance in YC_bC_r color space, we can detect face region and each facial feature. For face region, gray image of C_r will be used because as we can observed from Fig 3 that no matter which kind of people (white, negro or yellow race), their face region appear a strongly and independent characteristic in C_r subspace. So threshold value of face region can be easily confirmed from its' histogram.

2.1 Face Region Detection Using Color

Formula 1 ~ 3 showed the operation process to gain mask result and face region.

$$Cr_{Th} = w * \sum_{i=0}^{255} Hist(i) \tag{1}$$

$$\mathrm{Im}_{Mask}(i) = \begin{cases} 255, [if(Cr) > Cr_{Th}] \\ 0, [if(Cr) < Cr_{Th}] \end{cases} \tag{2}$$

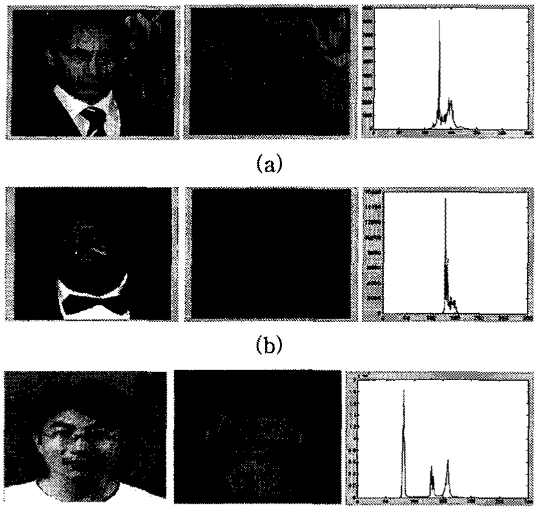


Fig. 3. C_r Image of 3 Kinds of Face Region and Histogram (where the first imge is source image; second is Cr sub-color image of source image and third is histogram of Cr gray value): (a). White; (b). Negro and (c) Yellow Race.

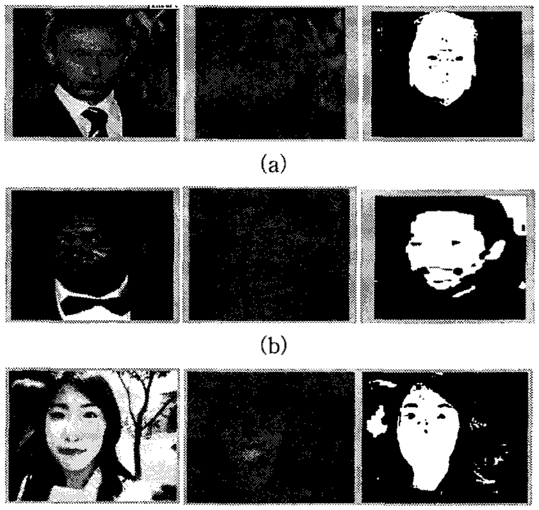


Fig. 4. Face Region Detection Result (where the first image is source image; second is Cr sub-color image of source image and third is histogram of Cr gray value): (a). White; (b). Negro and (c) Yellow Race.

$$\mathrm{Im}_{Face} = \mathrm{Im}_{Orig} \,\&\, \mathrm{Im}_{Mask} \tag{3}$$

Here, Im_{Mask} is symbol for mask image, and Im_{Org} original image, Im_{Face} is face region image, w is weight value for different skin color, we have observed that for yellow race its' value is between 0.6 and 0.7, for white is 0.2 and 0.4 and for negro is 0.5 and 0.6. Face region detection result is shown in Fig. 4.

2.2 Mouth Feature Detection

When face region detection finished, second step is to detect mouth position and contour feature, we can find that human mouth (either yellow race, white or negro) contains stronger red component but weaker blue component than other facial region, so in YC_bC_r color space C_r value of mouth region is greater than facial other and C_b value is lower, because of this mouth region gray level is also lower than other facial region. So we can utilize these characters to detect mouth region, Formula 4 ~ 7 showed the operation process to gain mask result and mouth region.

$$\mathrm{Im}_{MF} = \frac{\frac{\mathrm{Im}_{Cr}{}^2}{\Phi_1} \bullet \frac{\mathrm{Im}_{Cb}{}^2}{\Phi_2}}{\Phi_3} \tag{4}$$

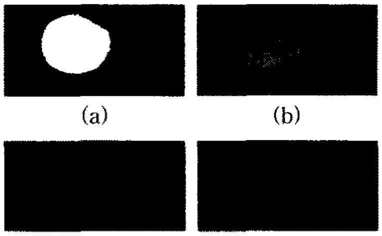
$$\phi_1 = 1.3\frac{1}{M \bullet N}\sum_{(i,j)\in M,N} \mathrm{Im}_{Cr} \tag{5}$$

$$\phi_2 = 1.3\frac{1}{M \bullet N}\sum_{(i,j)\in M,N} \mathrm{Im}_{Cb} \tag{6}$$

$$\phi_3 = 1.3\frac{\phi_1 + \phi_2}{2} \tag{7}$$

Here both $\mathrm{Im}_{Cr}{}^2$ and $\mathrm{Im}_{Cb}{}^2$ are normalized to range [0,255], and M, N is width and height of face image. Parameter ϕ_1 is estimated as an average value of C_r and ϕ_2 is an average value of C_b and ϕ_3 is an average value of C_r and C_b. Fig. 5 shows the operation result image:

For the pre-operated mouth feature image, we can employ a scan window to scan the mouth region by calculating every scanned region integral value, and select the maximum window which contained the mouth, we designate size of scan window is 1 / 6 of width and 1 / 14 of height. And



(a) (b) (c) (d)

Fig. 5. Mouth Feature Image and Pre-operating Image:(a). Face Region Image; (b). Face Region C_r Image; (c).Face Region C_b Image and (d). Pre-operated Mouth Feature Image

move the window from left-top to right-bottom. Operating Formula 8 is shown as following:

$$\underset{(m,n)\in M,N}{Win(m,n)} = \sum_{i=1}^{\frac{1}{4}M}\sum_{j=1}^{\frac{1}{6}N} \mathrm{Im}_{MF}(m+i,n+j) \quad (8)$$

2.3 Eyes Feature Detection

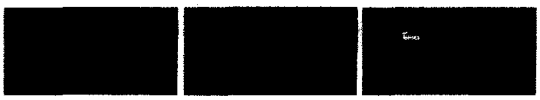
As the rule has presented that eyes is always on the top side of mouth, and left eye always on left side, right eye on right, so the detected face region mask image can be clipped to just contain left eye and eyebrow, then mask image of eye can be gained as formula 9 ~ 11 shown.

$$\mathrm{Im}_{LEF} = (Left\,\mathrm{Im}_{Mask} \,\&\, \mathrm{Im}_Y) * (Left\,\mathrm{Im}_{Mask} \,\&\, \mathrm{Im}_{C_r}) \quad (9)$$

$$LeftEye_{Th} = \frac{\sum_{(i,j)\in M,N} \mathrm{Im}_{LEF}(i,j)}{M*N} \quad (10)$$

$$LeftEye_{Mask} = \begin{cases} 255, if(\mathrm{Im}_{LEF} > LeftEye_{Th}) \\ 0, if(\mathrm{Im}_{LEF} < LeftEye_{Th}) \end{cases} \quad (11)$$

Here $LeftIm_{Mask}$ is mask image which has been clipped by the rule, and M, N is size of face rest region. $LeftEye_{Th}$ is threshold value of eye and eyebrow. In the result mask image, there contain both eye region and eyebrow region because their feature and distance is so nearly, so can not separate them, but fortunately their mask region is not connected, and based on rule c, we can get each distance from them to mouth by using geometry method and select the minimum distance region which is the left eye region. Fig. 6 shows the operation result image:



(a) (b) (c)

Fig. 6. Left Eye Detection Result: (a). Clipped C_r Region of Left Eye, (b). Clipped Y Reverse Region and (c). Eye Region Mask Image

For the right eye, it is similarly with method to search left eye

2.4 Eyebrow Feature Detection

Based on rule c, eyebrows have the nearest distance to eyes among all of face features and they are always on top side of eyes. So also by using geometrical method, we can gain distance between left eyebrow and left eye, or right eyebrow and right eye, then select the minimum distance which is eyebrow region. Fig 7 shows the result.

2.5 Nose Feature Detection

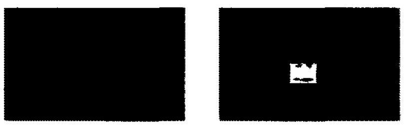
Based on Rule d, face mask image can be clipped to get the nose mask region image, then use lacal mean method to get threshold value and gain nose mask image, formula 12 shows the operation result.

$$Nose_{Th} = \frac{\sum_{(i,j)\in M,N} \mathrm{Im}_{Nose}(i,j)}{M*N} \quad (12)$$

Fig 8 shows the operation result.

(a) (b) (c)

Fig. 7. Eyebrow Detection Result:



(a) (b)

Fig. 8. Nose Detection Result: (a). Clipped Nose Region Gray Image and (b). Detection Result

3. FACE FEATURE MODALITY ANALYSIS AND FACE AVATAR CREATION

Different people with different facial feature, in order to analysis and classify them, we used key points for each face organ feature, relationship of these points can describe pattern for classifying the feature. In order to describe feature information enough for creating avatar, we define amount of each facial feature and their position as following:

1. Face outline: 12 points.
2. Mouth outline: 4 points.
3. Eye outline: 4 points.
4. Eyebrow outline: 4 points.
5. Nose outline: 4 points.

As shown in Fig 9.

3.1 Face Modality Type Analysis and Classification

Through analyzing plenty of face data (which have been presented in another paper of ours [14]), we concluded that there are totally 7 kinds of face modality for male and 7 kinds for female in the world. These types are as shown in Table 1. This

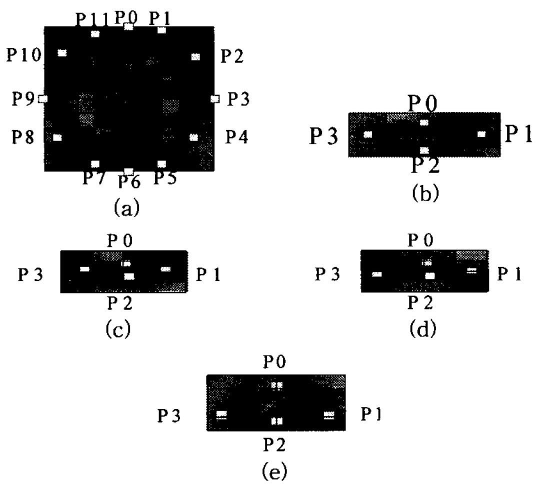
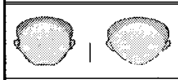
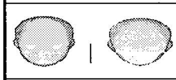
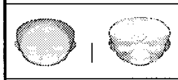
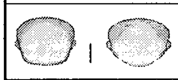
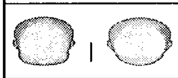
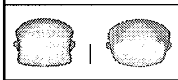
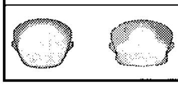


Fig. 9. Facial Feature Points Definition: (a). Face Outline, (b). Mouth Outline, (c). Eye Outline, (d). Eyebrow Outline and (e). Nose Outline

Table 1. Face Outline Classification

Face Modality (Male / Female)	Feature Point Distance Relationship
	$\|P3_xP9_x\| > \|P4_xP8_x\| > \|P5_xP7_x\|$, $\|P3_xP9_x\| > \|P10_xP2_x\| > \|P11_xP1_x\|$
	$\|P3_xP9_x\| \approx \|P4_xP8_x\| > \|P5_xP7_x\|$, $\|P3_xP9_x\| \approx \|P10_xP2_x\| \approx \|P11_xP1_x\|$
	$\|P3_xP9_x\| \approx \|P4_xP8_x\| > \|P5_xP7_x\|$, $\|P3_xP9_x\| \approx \|P10_xP2_x\| \approx \|P11_xP1_x\|$
	$\|P3_xP9_x\| \approx \|P4_xP8_x\| \approx \|P5_xP7_x\|$, $\|P3_xP9_x\| \approx \|P10_xP2_x\| \approx \|P11_xP1_x\|$
	$\|P4_xP8_x\| > \|P3_xP9_x\| > \|P5_xP7_x\|$ $\|P3_xP9_x\| \approx \|P10_xP2_x\| \approx \|P11_xP1_x\|$
	$\|P5_xP7_x\| > \|P4_xP8_x\| > \|P3_xP9_x\|$, $\|P3_xP9_x\| > \|P10_xP2_x\|, \|P10_xP2_x\| < \|P11_xP1_x\|$
	$\|P4_xP8_x\| > \|P3_xP9_x\| > \|P10_xP2_x\| > \|P11_xP1_x\|$, $\|P5_xP7_x\| < \|P4_xP8_x\|$

can be distinguished by using distance relationship of $|P4_xP8_x|$, $|P3_xP9_x|$, $|P5_xP7_x|$, $|P10_xP2_x|$ and $|P11_xP1_x|$. As we can observe from table that if people with a big chin, $|P5_xP7_x|$ is greater than $|P4_xP8_x|$, if small chin, $|P5_xP7_x|$ is smaller than $|P4_xP8_x|$, so we can classify face modality by utilizing difference of these distance. Table 1 shows the classification factors.

We can see from the table that there exist the same factor for some different face modality, this make them can not be distinguished, but through experiment we can observe that their specific value is so different, therefore threshold value can be used in the second step to distinguish these face modality in detail. Face avatar can be gained as Fig. 10 showed.

3.2 Mouth Modality Analysis and Classification

In order to create mouth avatar, we define 3 kinds of mouth modality. They can be distinguished by using mouth tail feature such as: tail to top, tail to middle or tail to bottom. And for each we define 3 kinds of lip type: Fan, Middle and Thin. Then for each lip type define 3 kinds of size: Narrow, Middle and Wide. Through observing fro

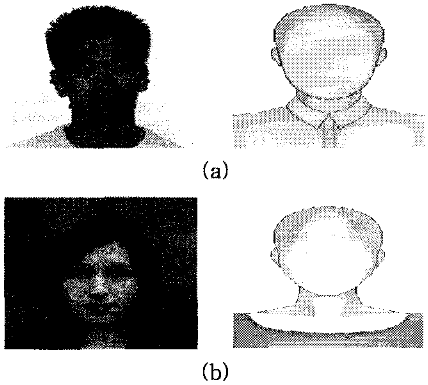


Fig. 10. Face Feature Point Detection and Avatar Creation Result: (a). Male and (b). Female.

m lots of samples, we concluded that P1 and P3 composed a horizontal line to separate mouth region, when mouth with tail to top,. pixel amount above the line is greater than below. Otherwise when mouth with tail to bottom, pixel amount above is lower. We can set threshold limit values through experiment, if pixel amount difference between above and below is inside the threshold limit values, then we can consider that mouth tail is to middle. This approach is as shown in Fig. 11.

For classifying lip style (Fan, Middle or Thin),

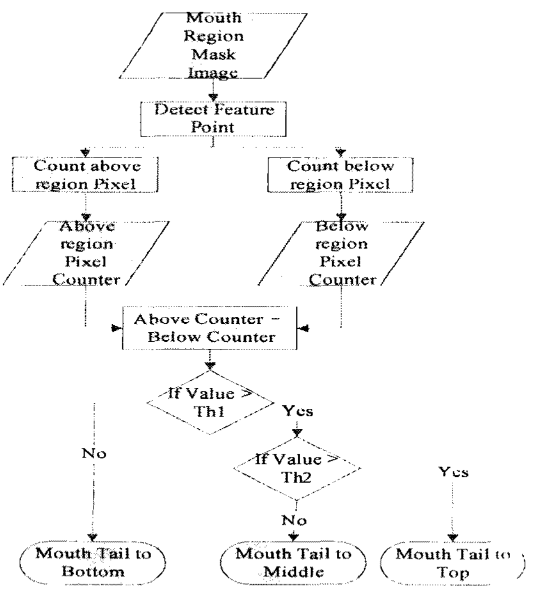


Fig. 11. Mouth Tail Type Classification Flow Chart.

we use distance from P2 to P4, and compare it with face region height. Fan lip with large proportion value, thin lip with small proportion value. So we can set threshold value to distinguish them. For classifying mouth size, it is a similar approach. Fig 12 shows mouth type classification and avatar creation result.

3.3 Eye Modality Analysis and Classification

We have defined 9 kinds of eye avatar type and Fig 13 shows the result of eye feature points detection and avatar classification result.

3.4 Eyebrow Modality Analysis and Classification

For eyebrow avatar, we defined 18 kinds of

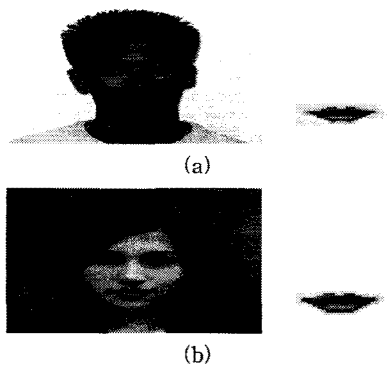


Fig. 12. Mouth Modality Classification and Avatar Creation Result: (a). Male and (b). Female.

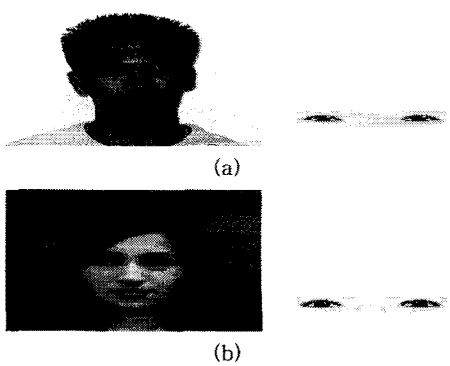


Fig. 13. Eye Modality Classification and Avatar Creation Result: (a). Male and (b). Female.

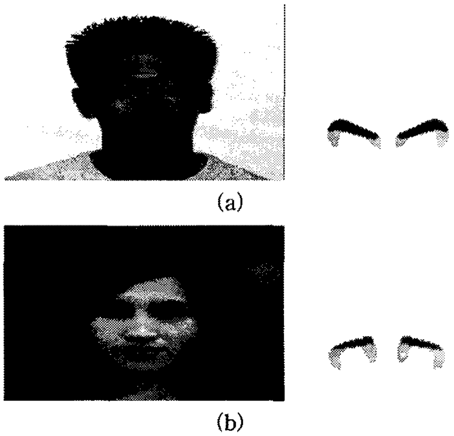


Fig. 14. Eyebrow Modality Classification and Avatar Creation Result: (a). Male and (b). Female.

eyebrow type, and the result is as shown in Fig 14.

3.5 Nose Modality Analysis and Classification

Meanwhile, for nose avatar, We defined 18 kinds of type, and use distance from P1 to P3 to confirm nose width, use distance form P0 to P2 to confirm nose height. The creation result is as shown in Fig 15.

4. EXPERIMENTAL RESULTS

For evaluating efficiency and accuracy of our proposed algorithm, we have made experiment on several face databases such as: NIST FERET database, BioID face database, Aleix face database, UMIST face database etc. And also we evaluated our algorithm on our self-build face image database.

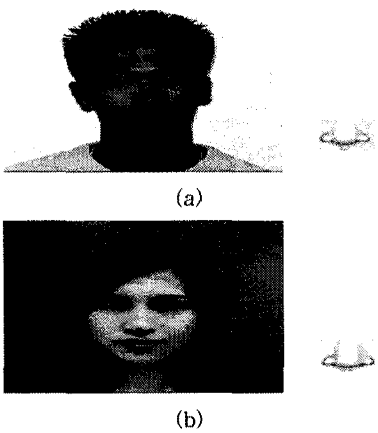


Fig. 15. Nose Modality Classification and Avatar Creation Result: (a). Male and (b). Female.

To consider the illumination condition, we test our algorithm in 3 kinds of lighting condition: 1. sunlight; 2.fluorescent lamp and 3. natural condition. Avatar creation result is controlled by face detection result and analysis result. So firstly we evaluate the detection effect of face detection algorithm and then evaluate the face feature analysis algorithm which is used to create avatar image. Table 2 will show the face detection experiment results and Table 3 will show analysis result of face feature analysis algorithm.

One of face avatar creation result is as shown in Fig 16.

And Fig 17 shows the result that applied the proposed algorithm on mobile device.

Table 2. Face Detection Experimental Results in Different Illumination

Lighting Condition	Test Image NO.	*Acceptable Image NO.*	Correct Rate
Sunlight	100	95	95%
Fluorescent lamp	100	96	96%
Natural condition	100	94	94%

Table 3. Face Feature Analysis Experimental Results

Lighting Condition	Correct Detection Image NO.	*Acceptable Image NO.*	Correct Rate
Daylight	95	87	87%
Fluorescent lamp	96	84	96%
Natural condition	94	90	90%

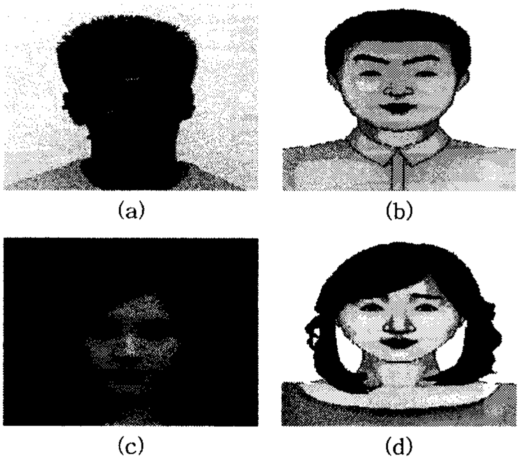


Fig. 16. Face Avatar Creation Result: (a). Male Face Feature Point Image, (b). Male Face Avatar Creation Result; (c). Female Face Feature Point Image and (d).Female Face Avatar Creation Result.

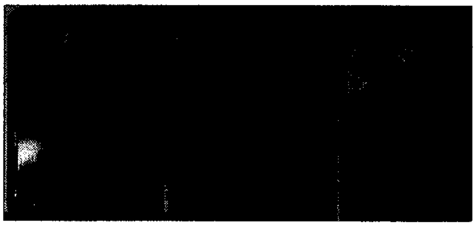


Fig. 17. Application of algorithm on mobile phone.

5. Conclusions

This paper proposed a novel face avatar creation algorithm which is based on face feature points. Firstly for searching face feature, we utilize face appearance feature and associated with knowledge method, the mean method is also used in every layer of detected image. First of all, we detect face region by using its' character in C_T subspace. Then detect mouth feature by using local mean method to confirm mouth region threshold value. Based on the rule which has been defined in this paper, searching scope can be decreased, so that each region threshold value which is gained by mean method can be more exactly. That make the final detection result can be more acceptable. The detection results then can be used to create face avatar, feature points have been defined for each feature, we can analyze geometry relationship of these feature points to link with a correspond avatar, in this way we can create a corresponding avatar for a people. The experiment has been finished, from which we can see that our proposed algorithm can be practicable.

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