Workshop on **Artificial Intelligence**

Facial Model Analysis for 2D Caricature Generating Systems

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Abstract

In this paper, we present a new interactive 2D caricature face generating system to create caricatures with various styles. Analysis and definition of import facial feature points as pattern matching primitives are discussed. Users define local coordinates of control feature points for each original real image, and these points will determine a unique transformed vector for matching with pre-generated facial models and features from database. Selected basic models will be re-drew for final representation according to the proportion of input real images. A 2D caricature face created from original facial characteristics can be utilized in several virtual Internet real-time applications, such as Internet games, net-meeting, distance learning, web advertisement, and so on. Due to the advantageous features of privacy, security, amusement and compact file size, the 2D caricature faces generation algorithm becomes a noticeable research topic.

Keywords: 2D caricature, facial models, pattern recognition

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Keywords: 2D caricature, facial models, pattern recognition

1. Background

Due to the uniqueness of individuality and polymorphism of facial models, the techniques of generating computerized facial images and its related applications have been flourishing research topics for more than two decades, such as face detection[1], facial expression[2], face recognition[3], facial feature extraction[4][5], and facial animation[7][8], etc.. Based on the distinctive shape of facial models, people can be recognized correctly and memorized profoundly at his first impression. Therefore, the facial shape model becomes an important factor for designing personal hair style, make-up, dress style, and even plastic surgery. To achieve the exaggerated effects or beyond realism features of faces, both image morphing and warping techniques are employed for better solutions[6]. In this paper, the main topic will focus on the methodology of classifying and drawing human facial shapes in terms of caricature. Each facial shape is classified and generated by computer algorithms for its final 2D caricature face.

There are several reasons for classifying facial shape into different models prior to generating caricature faces[9], such as smoothing the outline of face, emphasizing the polymorphism of facial models, and accelerating the face generating and modifying for different applications. In this paper, a caricature facial model is classified according to curvatures of face shape, aspect ratio and geometrical location. Basically, a face is segmented into three parts: upper part (from top of frontal to top of eyebrow), middle part (from top of eyebrow to nasal tip), and the bottom part (from nasal tip to bottom of the chin). Each part preserves different degree of curvatures and aspect ratios. In our proposed system, a facial model databank is clustered into 45 major classes and 720 complete facial types.

To identify a real face from facial model databank, we will simplify the defined feature points from a real face, and transform those feature points into a feature vector for further pattern matching. This simplification procedure will reduce the computational complexity of pattern recognition, smoothen the shape of caricature characteristics, and provide different visual effects by switching facial models efficiently and effectively. All these issue will be introduced in the later sections.

2. Caricature faces generating systems

2.1 System configuration

The proposed system for creating caricature faces is depicted in Figure 2.1. To consider the limitation of paper length here, we will only focus our discussion on models of facial outline and its related features. Other topics such as eyebrow, eye, nose, mouth, ear, and hair style will be reserved for future reports. In this system, the input of a frontal image is required for precise caricature creation. Once users define the bounding box of face image, the system will provides a set of average facial feature points for quick reference. At this moment, users have to modify the position of feature points manually in order to obtain the correct relative facial features for each face. After obtaining the definition of face feature points, the system divides into three major sub-modules: face shape, sense organ, and hair style. Each sub-module will analyze the coordinates of features points and transform them into feature vectors respectively. At the last step of system, feature vectors will be matched with pre-collected caricature database which contains different classes of sense organs, face shapes, and hair styles. Finally, the system will integrate those matched partial caricature character into a complete caricature face.

2.2 Modules Description

In order to obtain a resemblance 2D caricature face from the system, a clear front picture is suggested. The image can be acquired from CCD cameras or scanner devices. Severe shadow effects of input pictures or profile pictures may mislead the definition of feature points at wrong position from beginning. In this paper, there are 20 average feature points with respect to face shape attached on the face image automatically for default setting. Users can drag-and-drop these 20 points to its proper position interactively according to the outline of real face. This module employs closed B-spline techniques to connect and redraw the generated face contour according to the location of defined points. If the feature points are not defined correctly, the calculated close contour cannot be fitted on the real face image, and user have to adjust the control point manually until the face contour are matched approximately. Once the feature control points are derived, a feature vector containing contour-based and region-based shape elements will be calculated according to their geometrical coordinates. Each feature vector of facial organs will be applied pattern matching algorithms respectively to select the best candidate from pre-generated caricature database.

The feature control points in our system are defined by analyzing the physical skeleton of head shown in Figure 2.2(a) and referring to the set of 84 feature points from ISO/IEC MPEG-4 systems shown in Figure 2.2(b). Feature control points are subdivided in groups according to the region of the face they belong to, and numbered accordingly. There are total 171 feature points in our caricature face generating system and depicted on figure 2.2(c): 12 points for ears, 14 points for eyebrows, 40 points for eyes, 25 point for nose, 24 points for mouth, 20 points for face contour, 5 points for chin, and 31 points for hair style. For the part of face contour, we consider the important factor of concavo-convex skeleton structure and select 20 important feature points. These designated points are able to describe and redraw the face contour with its best representation and show in Figure 2.2(d). The relative position and selecting reasons of each feature point are described in Table 2.1.

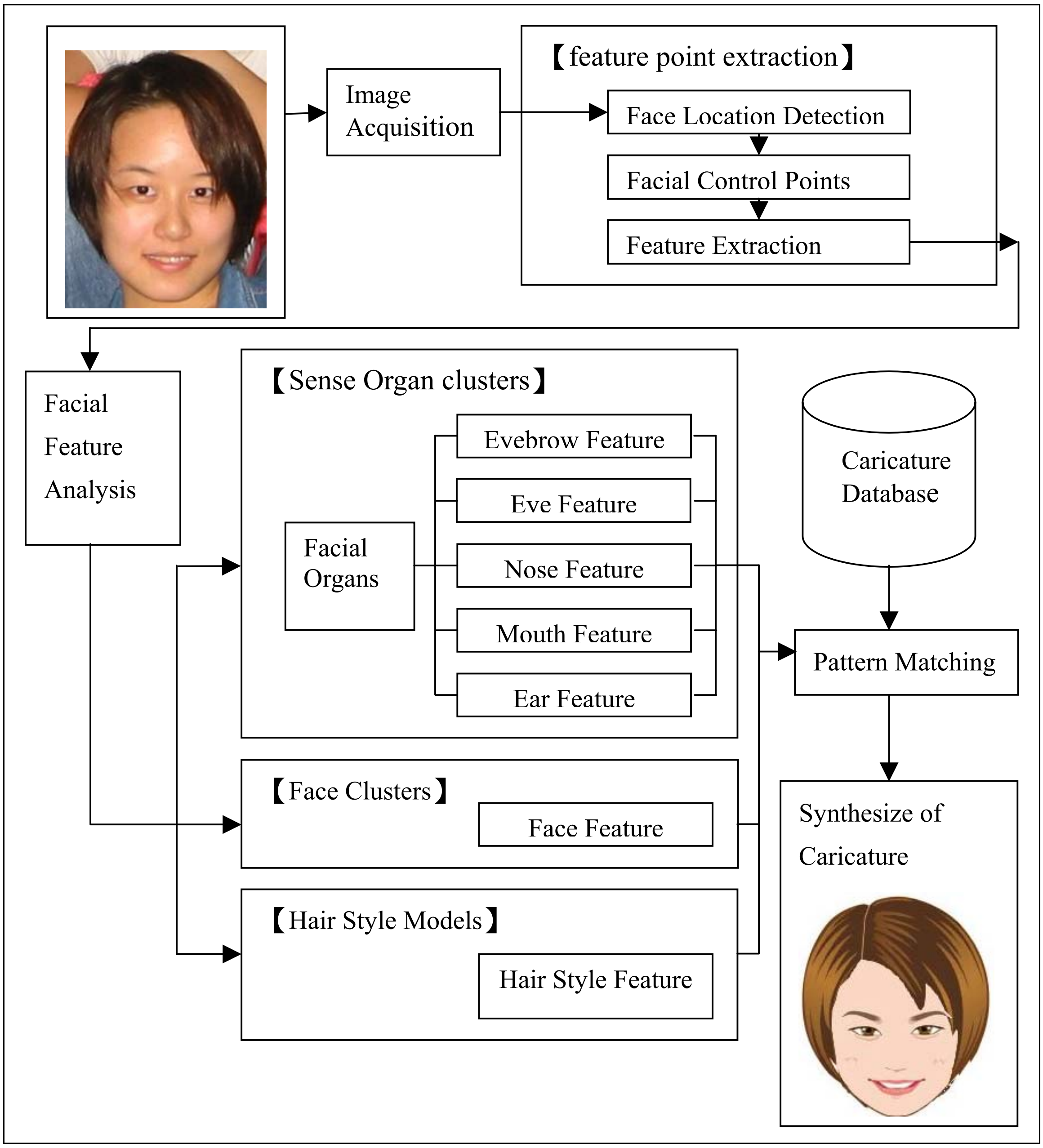


Figure 2.1 Caricature face generating system

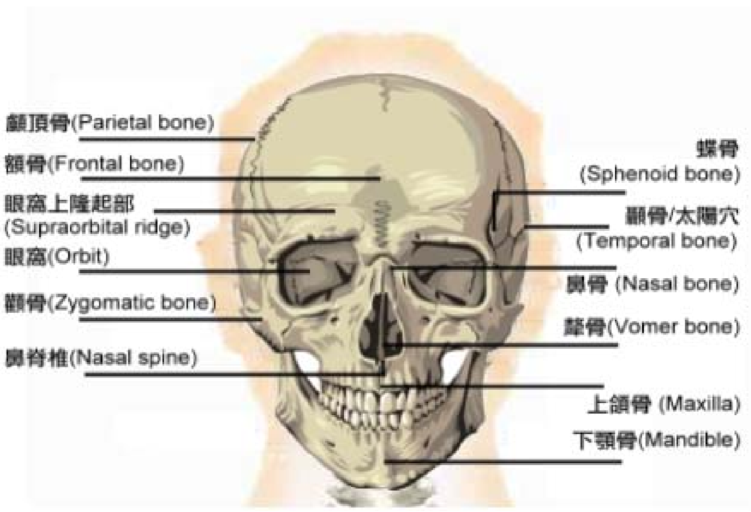


Figure 2.2 (a) Physical skeleton of head

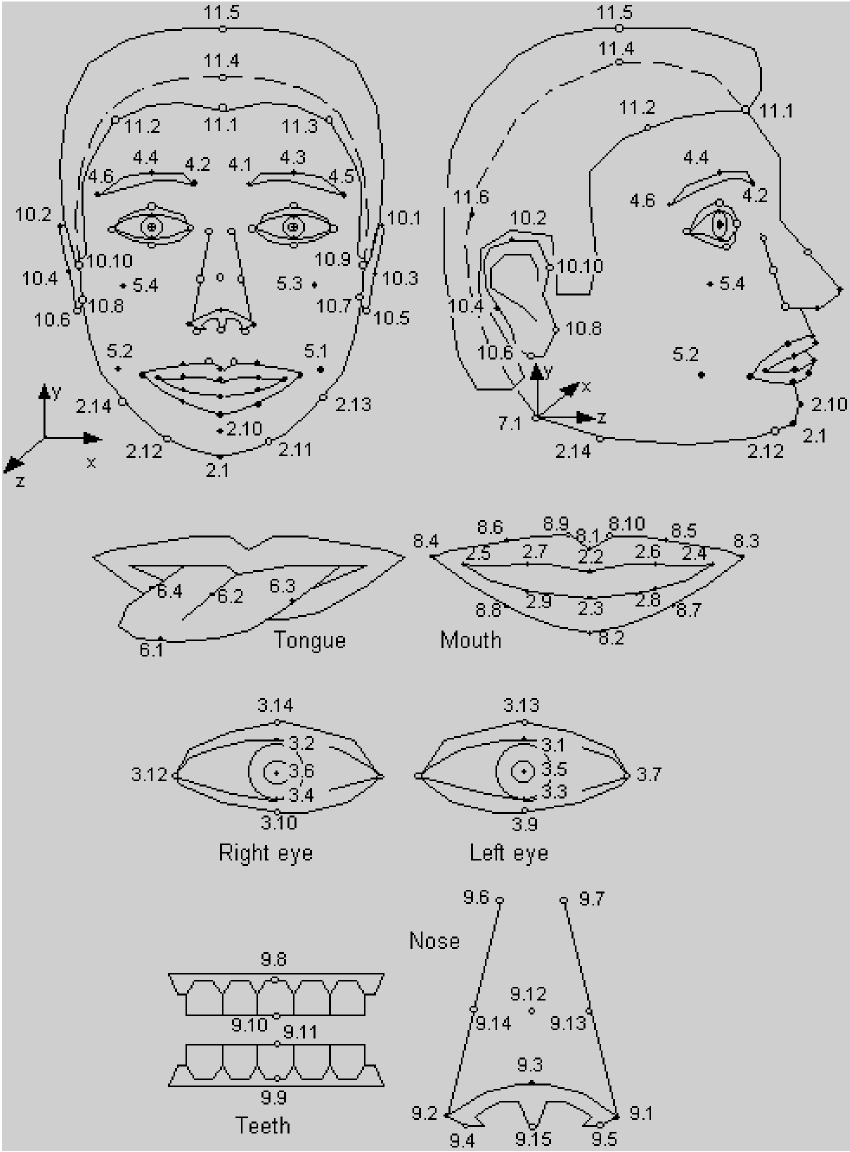
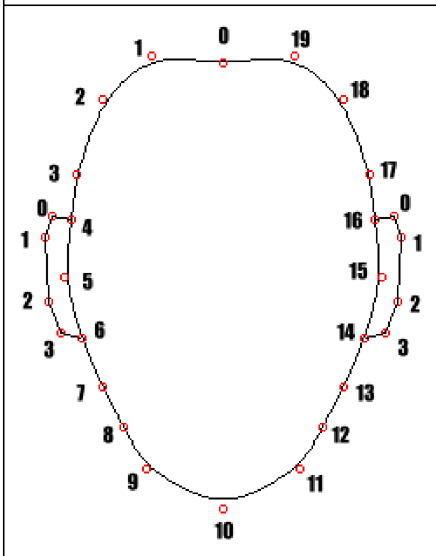
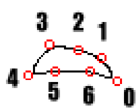
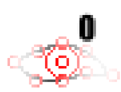
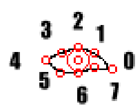
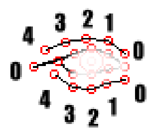
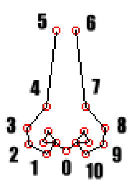
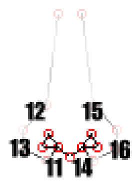
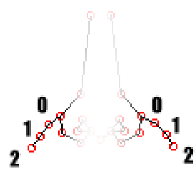


Figure 2.2 (b) 84 feature points from ISO/IEC MPEG-4 systems

Face contour	left eyebrow	right eye and related feature points	
		Right eyes and eyebrows possess symmetric feature points as left eyes in an anti-clockwise version	
	left pupil	left eye	Details of left eye
			
	nose	nostril	nasal-cheek outline
			

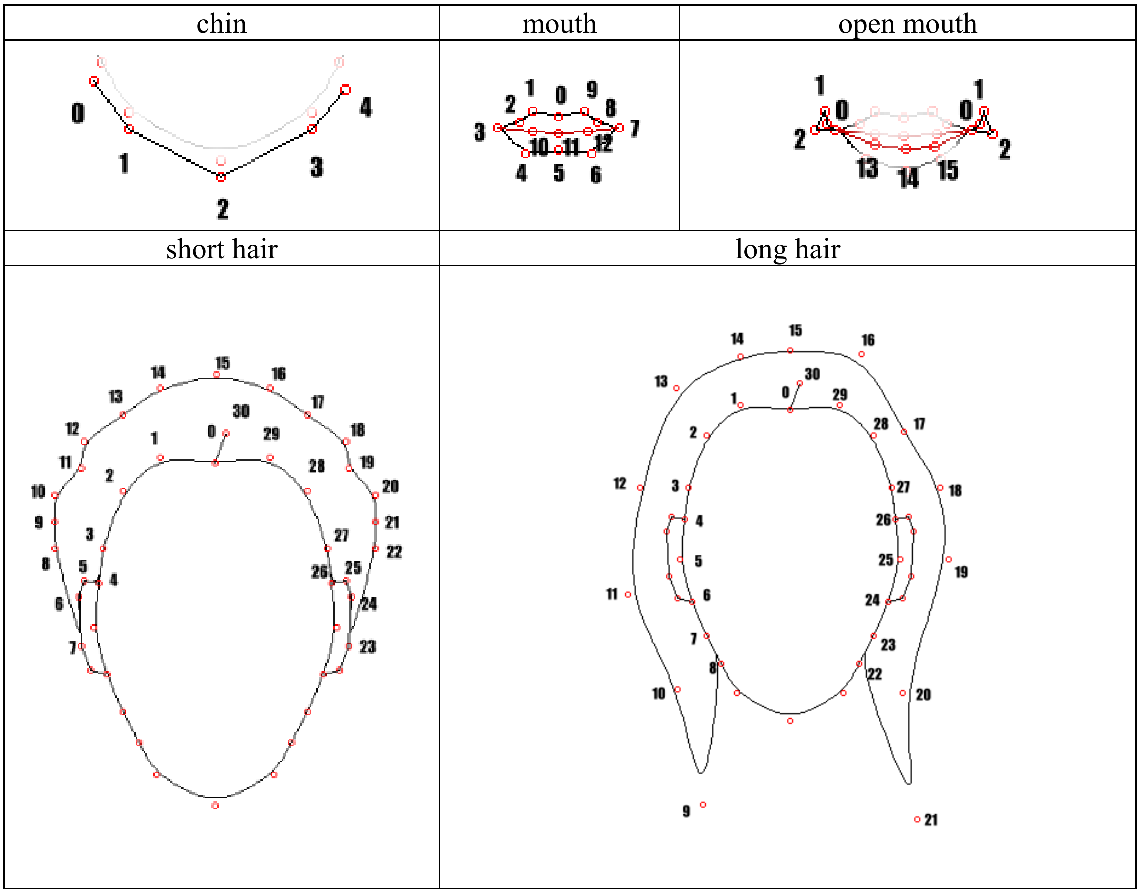


Figure 2.2(c) Complete feature points in caricature face generating system

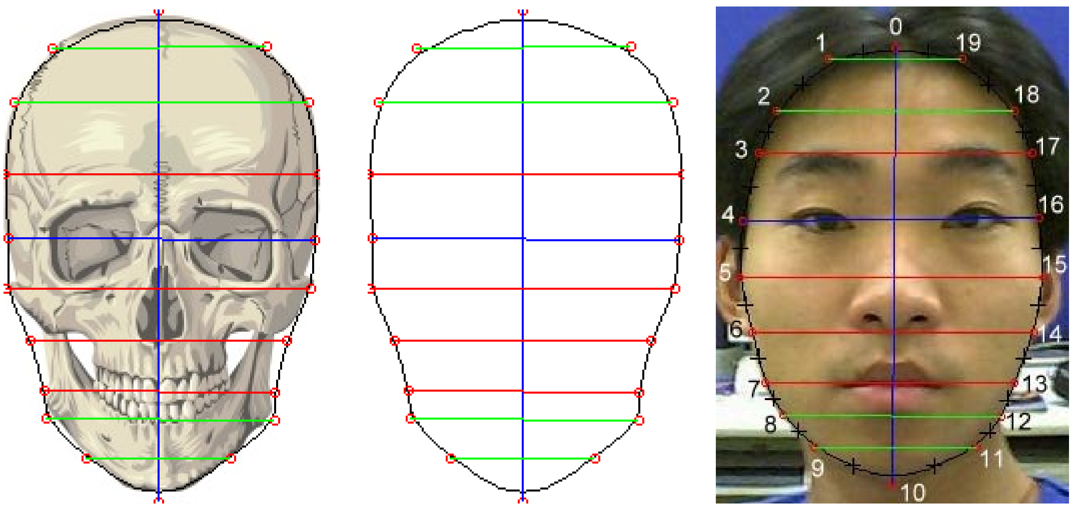


Figure 2.2(d) Examples of feature point for face contour

Feature Points	Point Location	Text Description
P_0	Top of Frontal	P_0 is on the top of frontal bone, and $\overline{P_0P_{10}}$ is the center vertical line of a face, which also represents the length of a face. A closed line of P_2-P_1-P_0-P_{19}-P_{18} represents the contour of forehead.
P_{10}	Bottom of Chin	P_{10} is on the bottom of chin, and closed line of P_9-P_{10}-P_{11} represents the contour of chin.

P_1 、P_{19}	Top of parietal tone	Forehead segment of facial model.
P_2 、P_{18}	Top of frontal bone	
P_3 、P_{17}	Top of eyebrow	
P_4 、P_{16}	Center line of pupils	Cheek segment of facial model. $\overline{P_4P_{16}}$ is the center horizontal line of a face.
P_5 、P_{15}	Zygomatic bone	
P_6 、P_{14}	Horizontal line of nasal tip	
P_7 、P_{13}	Horizontal line of central lip	Chin segment of facial model.
P_8 、P_{12}	Bottom line of mouth	
P_9 、P_{11}	Horizontal line of Mandible	

Table 2.1：Text description of feature points

3. Face Shape Classification

3.1 Shape Clusters

In the previous section, we have mentioned that a face is segmented into three parts: upper, middle, and bottom segments. We assume each face is symmetric with respect to the central vertical line. Therefore, we only have to consider left half or right half feature points of a face. From Figure 2.2(d), there are three segments on each side of a face shape and we can assign that the contour between point P_0 and P_3 belongs to the upper segment of a face contour, P_3 to P_6 for the middle segment, and P_6 to P_{10} for the bottom segment. Figure 3.1 shows the detail procedures of caricature face shape generation. At the first step, we have to drag and drop the 20 feature points manually to obtain the dedicate face contour. In order to reduce the number of clusters and smoothen the shape of caricature faces, it is acceptable to reduce the 20 feature points into 12 points. However, it is not an easy way to obtain the best 12 points directly without the prior procedure of 20 points allocation. Figure 3.2 shows the relative feature points between original and simplified version. Several examples of simplified version are shown in Figure 3.3 for demonstrating the smoothing results and remaining important shape features. The properties of each feature point and relationship between original 20 feature points and simplified 12 feature points are described in the following rules.

(a) major control points ($P^S_0, P^S_2, P^S_4, P^S_6$)：

$$P^S_0 = P^O_0 \;;\; P^S_2 = P^O_3$$

$$P^S_4 = P^O_6 \;;\; P^S_6 = P^O_{10}$$

Where P^S_i represents the i^{th} point in the simplified version, P^O_i represents the i^{th} point in the original version.

(b) curve control points (P^S_1, P^S_3, P^S_5)：

$$\textit{if}\ \ P^O_1(x,\cdot) < P^O_0(x,\cdot) - \mathrm{Dx}(P^O_1(x,\cdot), P^O_3(x,\cdot))/2\ \ \textit{then}$$

$$P^S_1 = P^O_1$$

Else

$$P^S_1 = P^O_{t3}$$

$$\textit{If}\ \ P^O_5 \le P^O_{t6}\ \ \textit{And}\ P^O_5 \le P^O_4\ \ \textit{then}$$

$$P^S_3 = P^O_5$$

$$\textit{Elseif}\ \ P^O_4 \le P^O_{t6}\ \ \textit{And}\ P^O_4 \le P^O_5\ \ \textit{then}$$

$$P^S_3 = P^O_4$$

Else

$$P^S_3 = P^O_{t6}$$

$$P^S_5 = P^O_{t10}$$

where Dx (P^O_1(x , •) , P^O_3(x , •)) is the distance in x-direction between point P^O_1 and P^O_3 , and P^O_{t3} is the tangent point between generated curve and line segment of (P^O_1,P^O_2) during closed B-spline processing.

(c) symmetric control points (P^S_7~P^S_{11}) :

P^S_7~P^S_{11} are obtained by symmetric position of P^S_1~P^S_5 reversely with respect to the center vertical line.

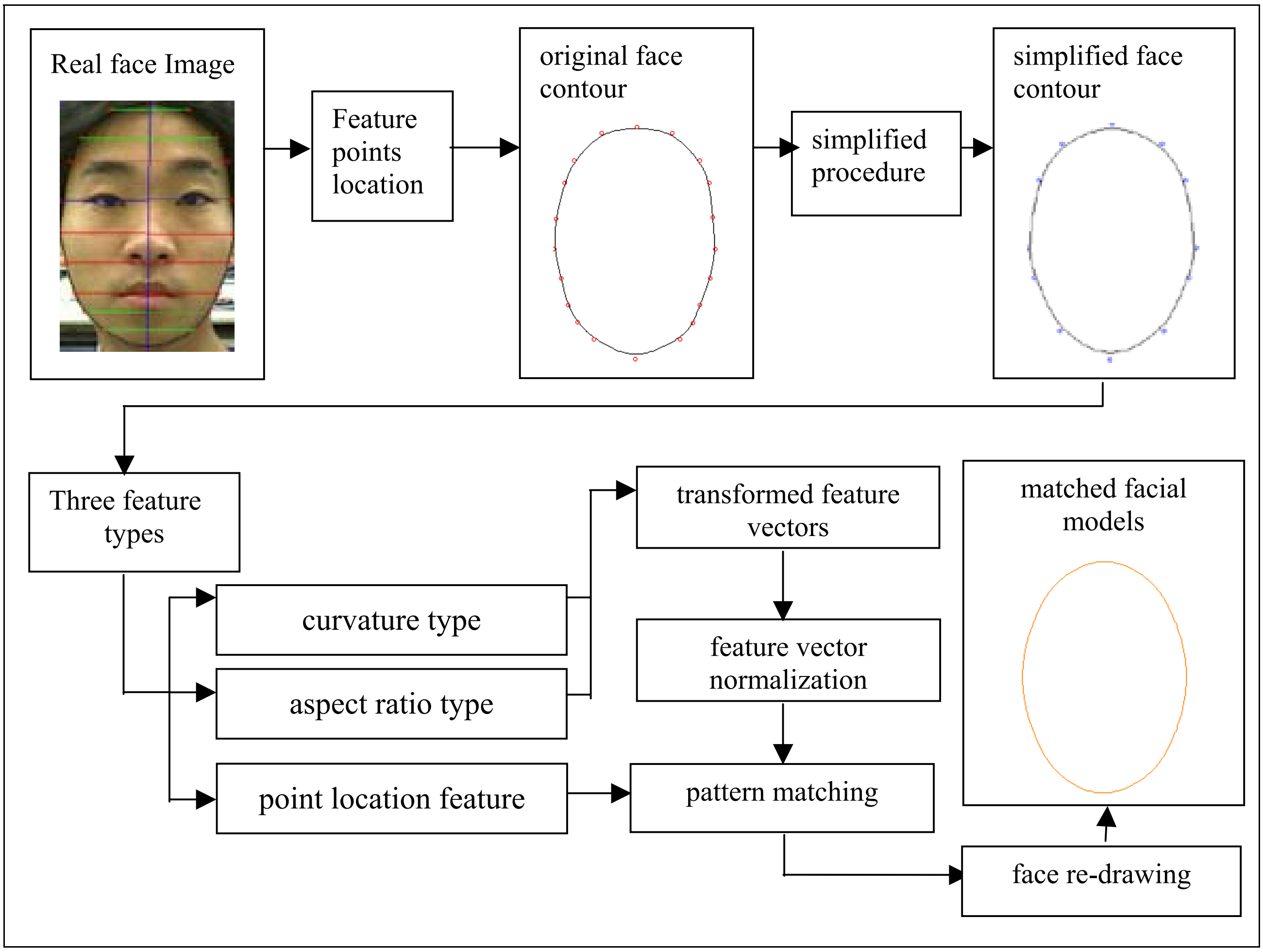
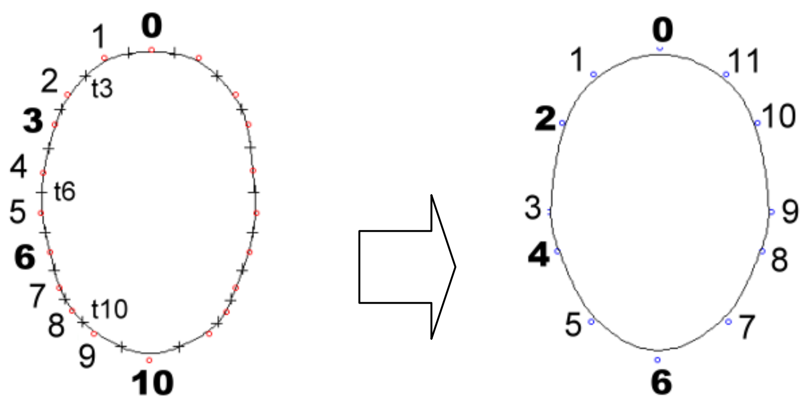


Figure3.1 The procedures of caricature face shape generation



Original version Simplified version

Figure 3.2 The relative feature points between original and simplified version

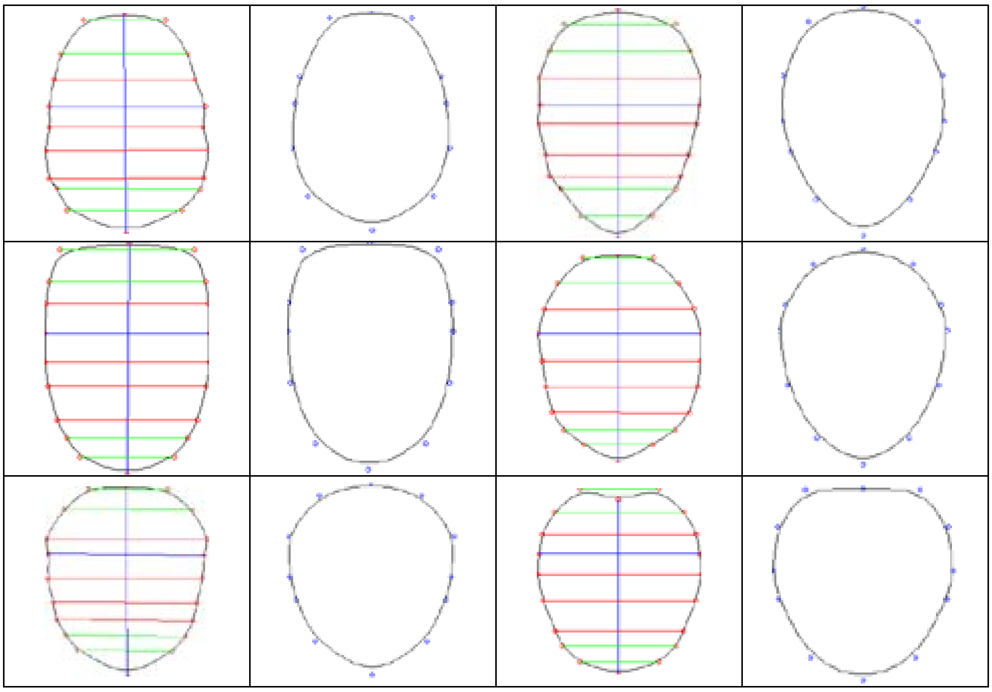


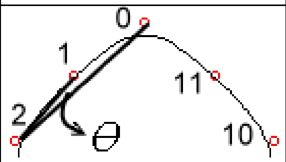
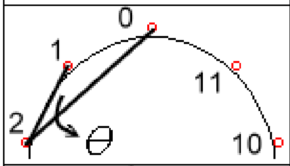
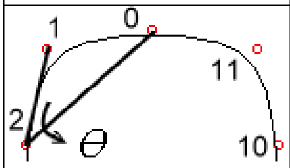
Figure 3.3 Examples of original and simplified feature points

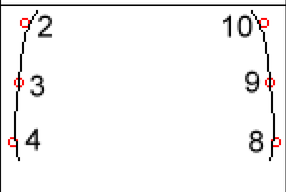
3.2 Feature Vectors

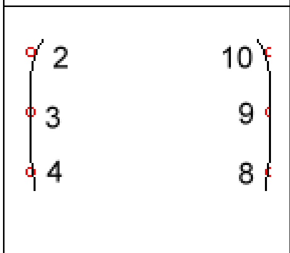
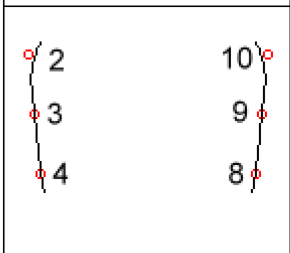
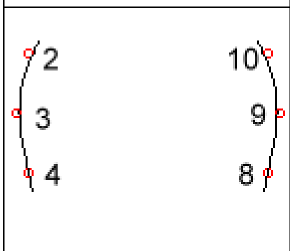
There are three basic feature types defined in our system for creating a caricature face; the first type is curvature property for each facial contour segment, the second feature type is aspect ratio for each facial segment (forehead, cheek, and chin sections), and the last feature is the geometrical location of feature points. The degree of curvature for each section and its criterion are listed and described in Table 3.1. For example, the upper part(forehead section) possesses 3 different conditions and encoded as "0", "1" and "2" respectively. The first condition is encoded as "0" representing angle θ less than 15°, and its shape looks more like straight line; the second condition is encoded as "1" representing angle θ between 15° and 25° and it possesses more degree of curvature; the last condition is encoded as "2" representing the upper part of face contour possessing most degree of curvature with angle $\theta > 25°$. Their respective contour lines are drew in the second column of Table 3.1. The middle part (cheek section) and bottom part (chin section) are analyzed by the same curvature feature and encoded as 5 and 3 different types respectively.

The second major feature is aspect ratio of each facial segment. This value is obtained by taking height of the bounding box dividing by its width. Different aspect ratios of facial segment reflect different caricature facial styles, and the feature can be exaggerated if someone possesses extra large or small value for a specific facial segment. For example, someone may have a long chin segment and a flat forehead segment. High aspect ratio of the facial segment is flat-like in general case, and low value for weasel-faced. Figure 3.3 and Table 3.2 show computational rules and threshold values for classifying each facial segment. The relationship of ratios from real faces, encoded feature indices, and the final values for re-generating caricature faces are discussed as well.

In terms of aspect ratio, there are three values including BoxUp.R, BoxMid.R, and BoxBtm.R need to be evaluated respectively. However, there are more than 95% of the values of Boxmid.R from our existed real face database (more than 1200 facial pictures) which possess the values in the range of [0.8, 1.1]. Therefore, the discrimination of feature Boxmid.R becomes less important, and the feature will be neglected in our caricature face generating system. Table 3.3 shows the features and their respective encoded indices for each discussed features so far. Based on above analysis, there are 720 types of face models generated in advance in our proposed system.

Location	shape condition	Encoded feature	criterion	Feature description
UpperPart $P^S_0 \sim P^S_2$ (foreHead) ShapeUp		0	$\theta = \angle P^S_1 P^S_2 P^S_0$ *If* $\theta < 15°$ *ShapeUp* $= 0$ *elseif* $15° \le \theta < 25°$ *ShapeUp* $= 1$ *else* $\theta \ge 25°$ *ShapeUp* $= 2$	Less curvature
		1		Medium curvature
		2		Larger curvature

MiddlePart
$P^S_2 \sim P^S_4$
(Cheek)
ShapeMid
		0	*BasicH* $= Dy(P^S_2, P^S_4)\ /3$
			If $P^S_3(x,\bullet) > P^S_4(x,\bullet)$ *And* $P^S_3(x,\bullet) > P^S_2(x,\bullet)$
			ShapeMid $= 4$
			Elseif $P^S_2(x,\bullet) = P^S_4(x,\bullet)$ *Or* $D(P^S_2, P^S_4) \le 4$
			If $(P^S_3(x,\bullet) = P^S_2(x,\bullet))$ *or* $(P^S_3(x,\bullet) = P^S_4(x,\bullet))$ *or* $(D(P^S_3, P^S_2) \le 2)$ *or* $(D(P^S_3, P^S_4) \le 2)$ *then*
			ShapeMid $= 1$
			Elseif *ShapeMid* $= 3$
			Elseif $P^S_4(x,\bullet) \le P^S_2(x,\bullet) - 5$ *then*
			If $(P^S_3(x,\bullet) > P^S_4(x,\bullet))$ *and* $(P^S_3(x,\bullet) < P^S_2(x,\bullet))$ *then*
			ShapeMid $= 0$
			Elseif $(P^S_3(x,\bullet) \le P^S_4(x,\bullet))$ *and* $(P^S_3(x,\bullet) \le P^S_2(x,\bullet))$ *then*
			if $P^S_4(\bullet,y) \ge P^S_2(\bullet,y) + 2*BasicH$
			ShapeMid $= 0$
			else *ShapeMid* $= 3$
			Elseif $P^S_4(x,\bullet) \ge P^S_2(x,\bullet) + 5$ *then*
				Shape of cheek segment getting wider

		1		Shape of cheek segment maintaining straight
		2		Shape of cheek segment getting narrower
		3		Shape of cheek segment possessing convex shape

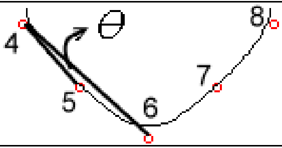
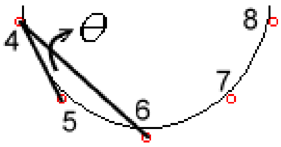
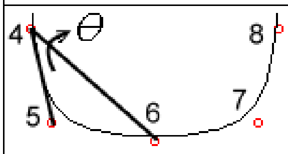
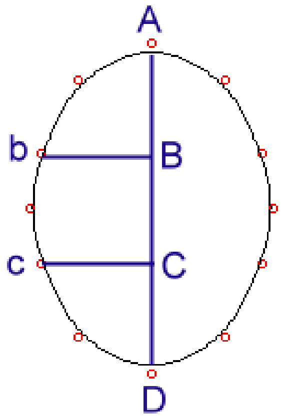
		4	*then* *If* $(P^S_3(x,\cdot) \le P^S_4(x,\cdot))$ *and* $(P^S_3(x,\cdot) \ge P^S_2(x,\cdot))$ *then* *ShapeMid* = 2 *Elseif* $(P^S_3(x,\cdot) < P^S_4(x,\cdot))$ *and* $(P^S_3(x,\cdot) < P^S_2(x,\cdot))$ *then* *if* $P^S_3(\cdot,y) \ge P^S_2(\cdot,y) + 2*BasicH$ *then* *ShapeMid* = 2 *else* *ShapeMid* = 3	Shape of cheek segment possessing concave shape
BottomPart $P^S_4 \sim P^S_6$ (Chin) ShapeBtm		0	$\Theta = \angle P^S_5 P^S_4 P^S_6$ *If* $\Theta < 15°$ *ShapeBtm* = 0 *elseif* $15° \le \Theta < 25°$ *ShapeBtm* = 1 *else* $\Theta \ge 25°$ *ShapeBtm* = 2	Less curvature
		1		Medium curvature
		2		Larger curvature

Table 3.1：Facial features extraction



$$BoxUp.R = \frac{\overline{AB}}{\overline{Bb}}$$

$$BoxMid.R = \frac{\overline{BC}}{(\overline{Bb}+\overline{Cc})/2}$$

$$BoxBtm.R = \frac{\overline{CD}}{\overline{Cc}}$$

Figure 3.3 Definition of aspect ratios

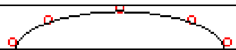
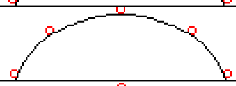
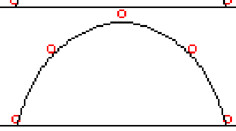
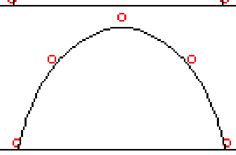
Range of aspect ratio	Encoded index	example	Feature description	Generating value V
R ＜ 0.5	0		Flat	0.3
0.5≤ R ＜0.8	1		Medium flat	0.6
0.8≤ R＜1.1	2		General case	1
R ≥ 1.1	3		Long	1.2

Table 3.2：threshold values, encoded indices, facial contours, and values for computer generating ratios(example of forehead facial segment).

Feature Element	BoxUp	BoxBtm	ShapeUp	ShapeMid	ShapeBtm	（BoxMid）
Encoded Indices	0、1、2	0、1、2	0、1、2	0、1、2、3、4	0、1、2	（0、1、2）

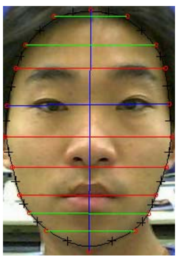
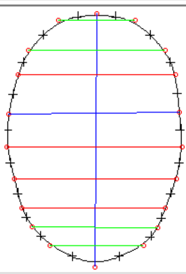
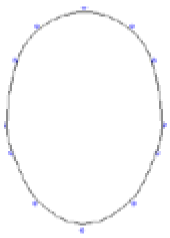
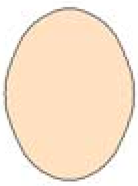
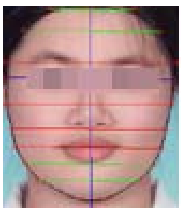
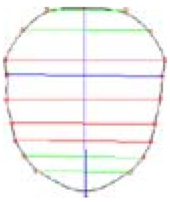
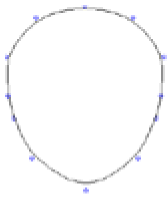
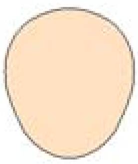
Table 3.3：Curvature and aspect ratio feature elements and respective encoded indices (total 720 types)

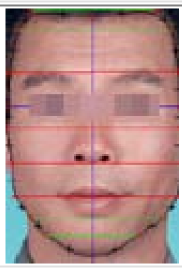
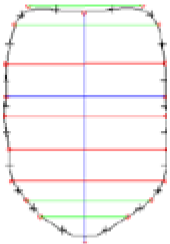
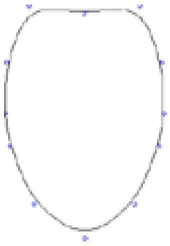
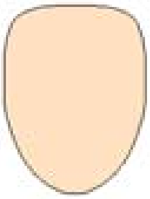
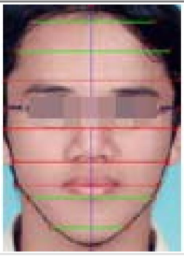
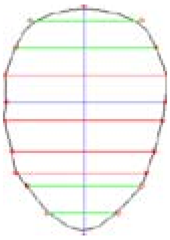
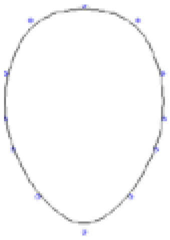
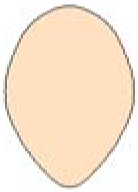
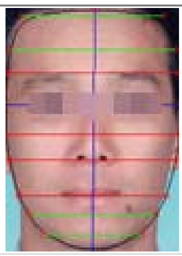
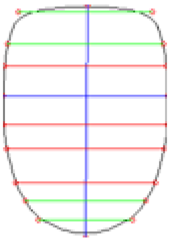
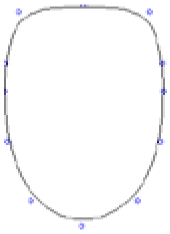
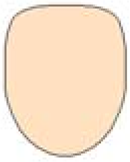
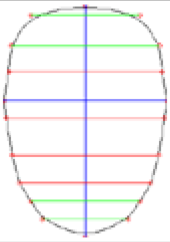
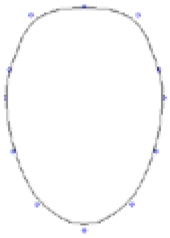
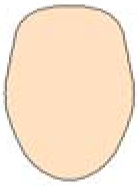
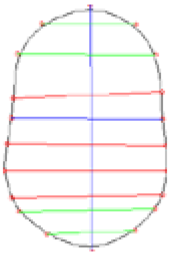
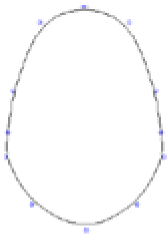
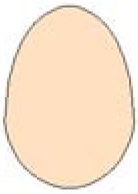
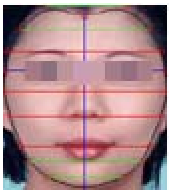
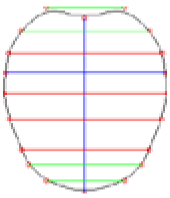
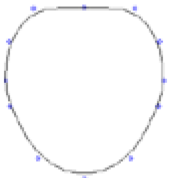
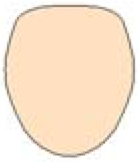
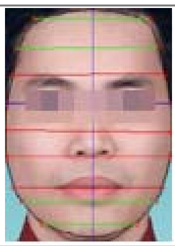
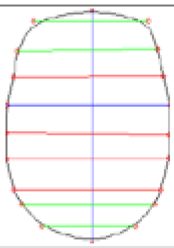
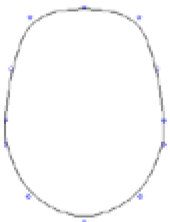
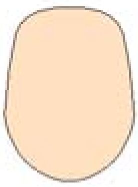
The third important feature element for matching a facial model from database is the geometrical location of feature points. Base on the Euclidean distance measurement, mean square error between feature points of a real face and computer generated caricature faces will be evaluated respectively and summed up for comparison. Without lost of generation, the smaller error of geometrical distance provides better facial models for pattern matching.

Curvature, aspect ratio, and geometrical location will be combined as a single feature vector for next module. General pattern matching techniques are employed and one of the best caricature facial models will be selected from previous generated 720 face shape database according to its final score. The smallest score is obtained from the following equation:

$$\min_{D}\{\frac{1}{2}\sqrt{\frac{1}{12}\sum_{i=0}^{11}(P_i^S-P_i^D)^2}+\sum_{j=1}^{5} f_j^S \otimes f_j^D\}$$

where P_i^S and P_i^D represent the i^{th} feature point of simplified input face and facial models from computer generated databank, f_j^S and f_j^D represent the encoded indices of curvature and aspect ratio of simplified input face and facial models from computer generated databank, $f_j^S \otimes f_j^D$ is an exclusive OR operation, and D is the index from 720 generated facial models. Figure 3.4 shows some examples of real images and their matched facial models. The final scores and encoded feature indices are shown as well.

Original Image	Original feature points	Simplified feature points	Matched facial model	Feature vector and Final score
				Feature vector : 22131 Score: 4.99885
				Feature vector : 12131 Score: 6.152415

				Feature vector : 13211 Score: 5.850773
				Feature vector : 23130 Score: 4.88924
				Feature vector : 12211 Score: 3.751247
				Feature vector : 22231 Score: 6.559932
				Feature vector : 32101 Score: 7.504465
				Feature vector : 12231 Score: 4.323569
				Feature vector : 22201 Score: 3.558973

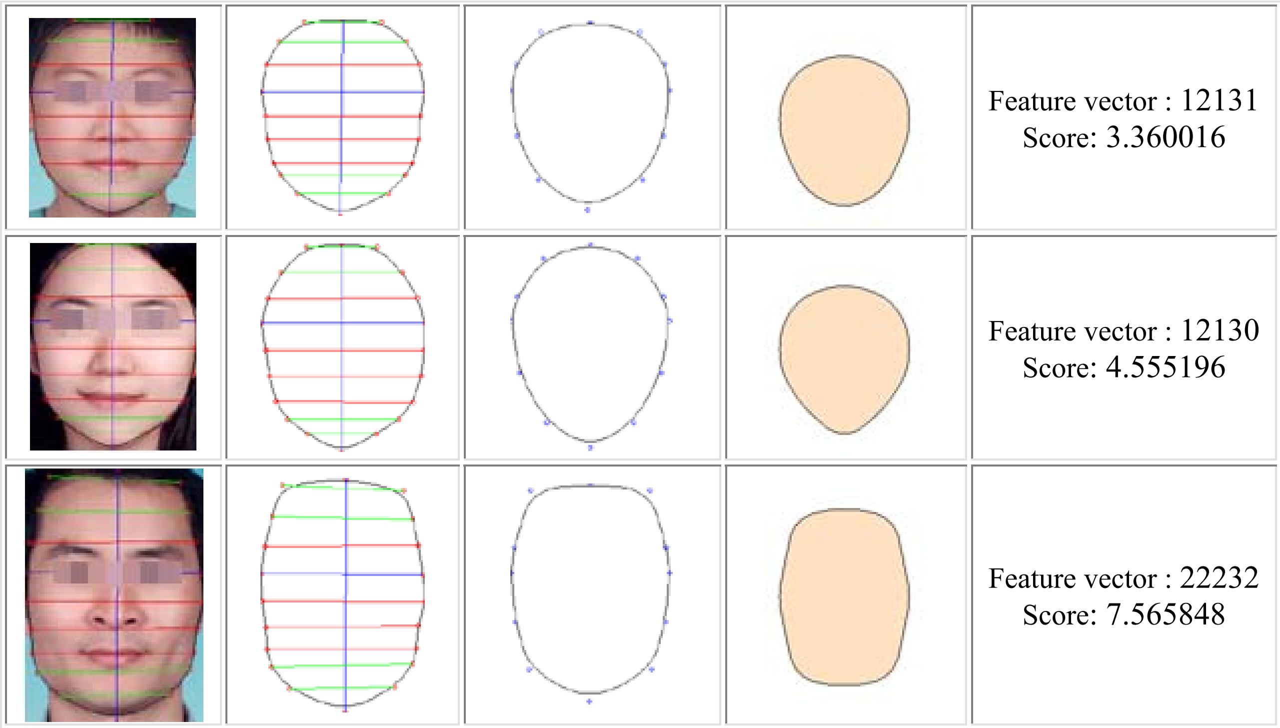


Figure 3.4 Several examples of matched facial models

4. Caricature Face Creation

Once the basic facial model is obtained, the system will calculate the normalized scale and re-drawing the caricature face to fit the right proportion of original face image. The main purpose of re-drawing caricature face from basic facial models considers the proper proportional relationship between forehead, cheek , and chin segments of an input face image. With appropriate proportion in re-drawing algorithms, the created caricature faces present more real version of cartoon characters. For exaggerating effects of caricature faces, the normalize scale can be modified in order to achieve various combinations with different sizes and in different locations. User can even add more exaggerated eyes, noses, mouths, and hair styles for an infinite number of caricature faces of the input image. The computational algorithms for re-drawing are executed according the following steps:

(1) Select $P^S{}_0$ and $P^S{}_6$ and calculate the vertical length of face.

(2) Calculate the normalized scale factor R_u and decide $P^S{}_2$ and $P^S{}_4$.

$$R_u = \frac{D(P^S{}_0, P^S{}_6)}{BoxUp.R + BoxMid.R + BoxBtm.R}$$

$$P^S{}_2(x,\cdot) = P^S{}_0(x,\cdot) - R_u;\ P^S{}_2(\cdot,y) = P^S{}_0(\cdot,y) + BoxUp.R * R_u$$

$$P^S{}_4(x,\cdot) = P^S{}_6(x,\cdot) - R_u;\ P^S{}_4(\cdot,y) = P^S{}_6(\cdot,y) - BoxBtm.R * R_u$$

(3) Calculate $P^S{}_1$, $P^S{}_3$, and $P^S{}_5$

$$P^S{}_1(x,\cdot) = P^S{}_2(x,\cdot) + BoxUp.R * D_x(P^S{}_0, P^S{}_2);$$

$$P^S{}_1(\cdot,y) = P^S{}_0(\cdot,y) + BoxUp.R * D_y(P^S{}_0, P^S{}_2)$$

$$P^S{}_2(x,\cdot) = P^S{}_4(x,\cdot)$$

$$If\ \ BoxMid = 0\ \ then\ \ P^S{}_4(x,\cdot) = P^S{}_2(x,\cdot) - D_x(P^S{}_0, P^S{}_2)/10$$

$$P^S{}_3(x,\cdot) = (P^S{}_4(x,\cdot) + P^S{}_2(x,\cdot))/2;\ P^S{}_3(\cdot,y) = (P^S{}_4(\cdot,y) + P^S{}_2(\cdot,y))/2$$

Else BoxMid = *1* *then*

$$P^S_3(x,\bullet) = P^S_2(x,\bullet)\ ;\ P^S_3(\bullet,y) = (P^S_4(\bullet,y) + P^S_2(\bullet,y))/2$$

Else BoxMid= *2* *then* $P^S_4(x,\bullet) = P^S_2(x,\bullet) + D_x(P^S_0,P^S_2)/10$

$$P^S_3(x,\bullet) = (P^S_4(x,\bullet) + P^S_2(x,\bullet))/2\ ;\ P^S_3(\bullet,y) = (P^S_4(\bullet,y) + P^S_2(\bullet,y))/2$$

Else BoxMid = 3 then

$$P^S_3(x,\bullet) = P^S_2(x,\bullet) - D_x(P^S_0,P^S_2)/10\ ;\ P^S_3(\bullet,y) = (P^S_4(\bullet,y) + P^S_2(\bullet,y))/2$$

Else BoxMid = 4 then

$$P^S_3(x,\bullet) = P^S_2(x,\bullet) + D_x(P^S_0,P^S_2)/10\ ;\ P^S_3(\bullet,y) = (P^S_4(\bullet,y) + P^S_2(\bullet,y))/2$$

$$P^S_5(x,\bullet) = P^S_4(x,\bullet) + BoxBtm.R * D_x(P^S_4,P^S_6)\ ;$$

$$P^S_5(\bullet,y) = P^S_0(\bullet,y) - BoxBtm.R * D_y(P^S_4,P^S_6)$$

(4) Based on symmetrical assumption, P_7 to P_{11} are obtained from P_1 to P_5 respectively.

(5) Using closed B-spline technique to generate face contour.

5. Experimental Results

Two examples of computer generated caricature faces will be shown in this section: the first person in Figure 5 is "Chih-Yao", one of the authors who builds up the system, and the second person in Figure 6 is the famous actress "Marilyn Monroe"(1926~1962). From these figures, we can see the final matched 2D caricature faces with minimum error which represent the distinguish characteristics of original faces, and various combination of proposed features for new facial models which represent interesting or exaggerating effects from cartoon drawing.

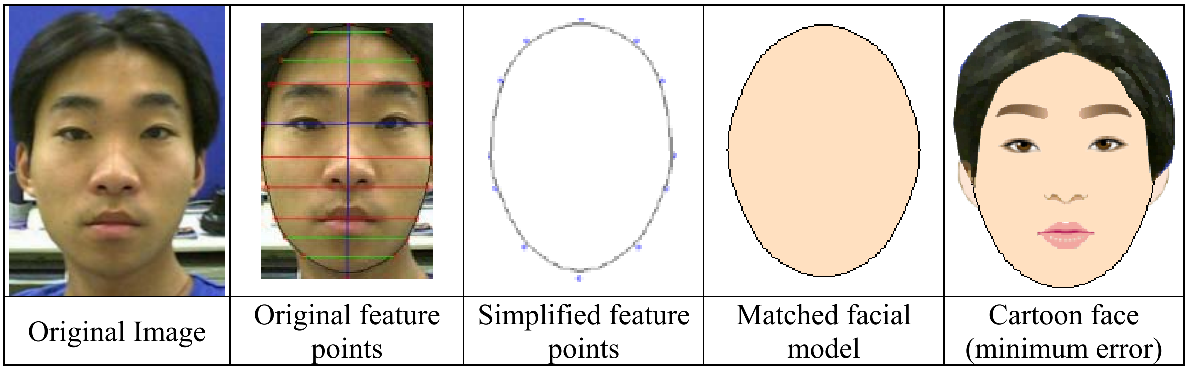


Figure 5 (a) : Example of input image and its selected cartoon face

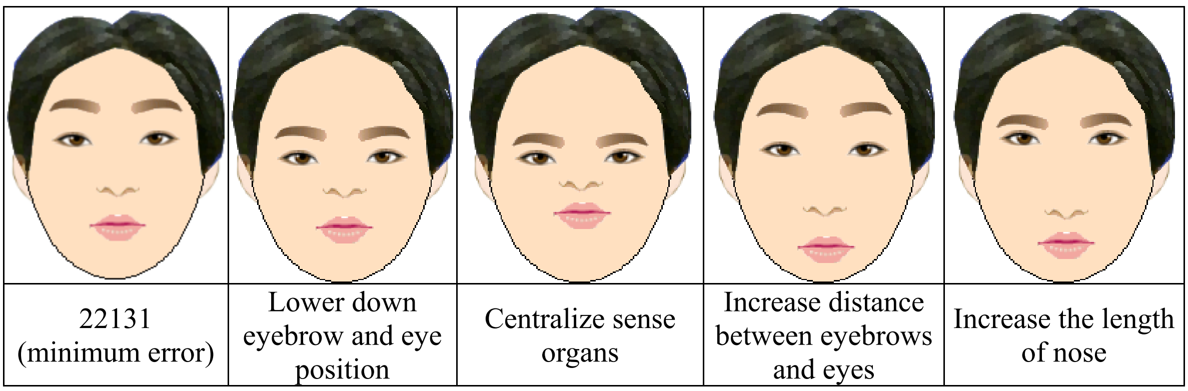
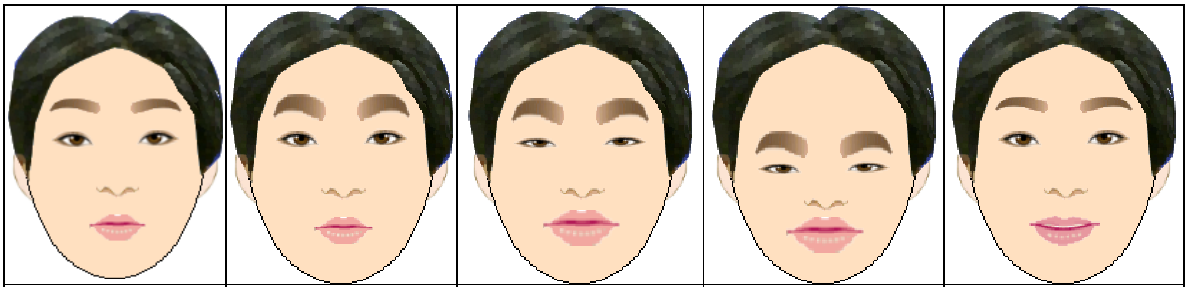
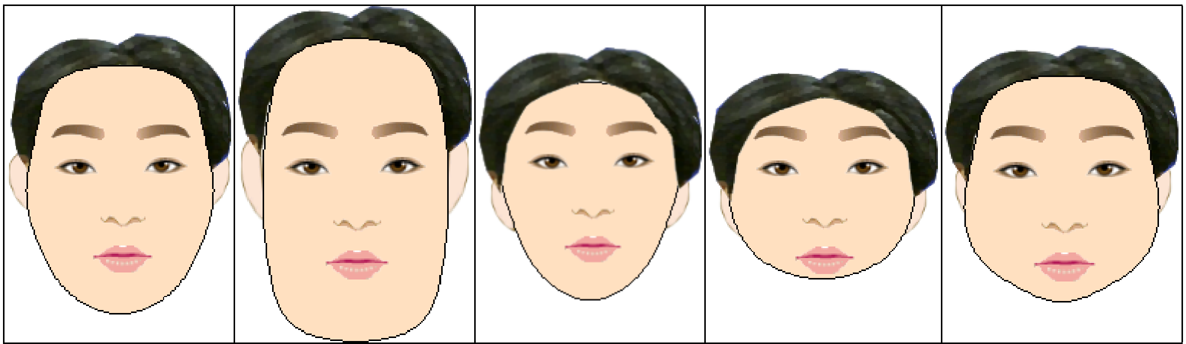


Figure 5 (b) : Same facial model, but different position of sense organs



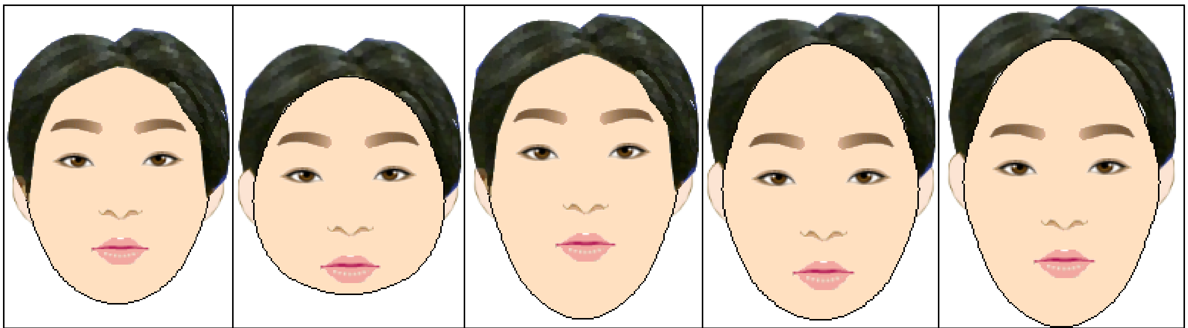
22131 (minimum error)	Exaggerate eyebrows	Exaggerate eyebrow, eye, and mouth	Exaggerate sense organs and centralize	Different Expression

Figure 5 (c) : Same facial model, but different type of sense organs



22231 (minimum error)	33212 (shape feature)	13131 (shape feature)	11131 (shape feature)	21200 (shape feature)

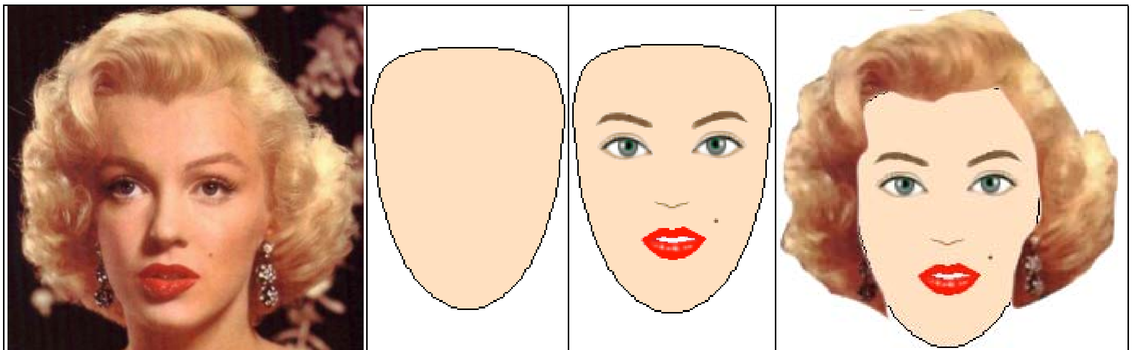
Figure 5 (d) : Different facial models, but the same type of sense organs



22131 (minimum error)	21131 (shorten chin)	23131 (lengthen chin)	32131 (enhance forehead)	33131 (enhance forehead and chin)

Figure 5 (e) : Same facial model, but different aspect ratios for each segment

Figure 5 : Examples of various cartoon faces from a real image



Original Image	13221 Matched facial model	Pattern matching	Final 2D cartoon face

Figure 6(a) : Example of image Marilyn Monroe and selected cartoon face

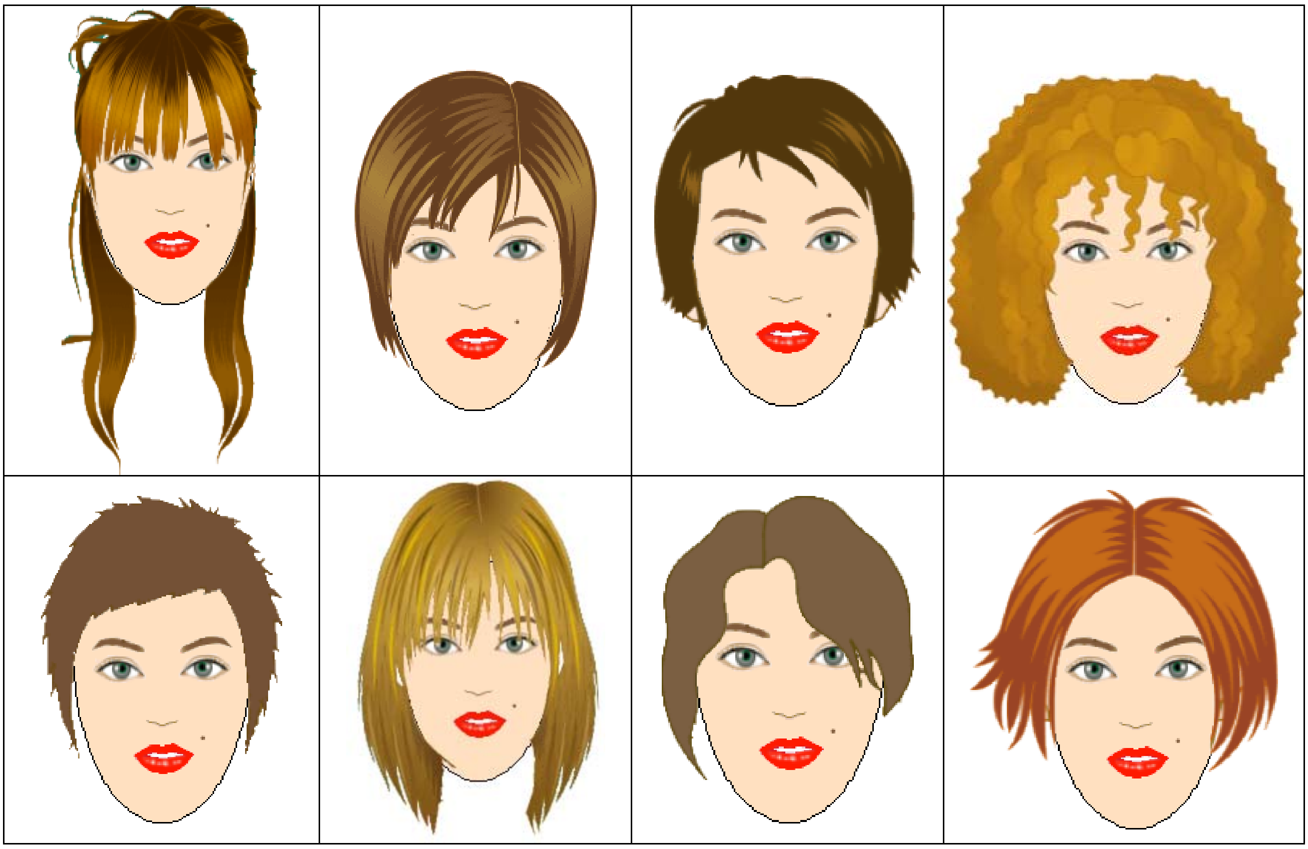
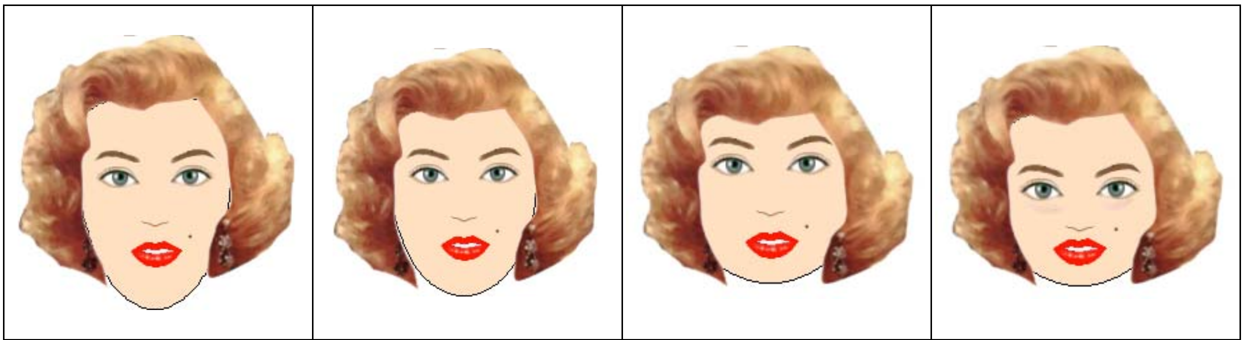
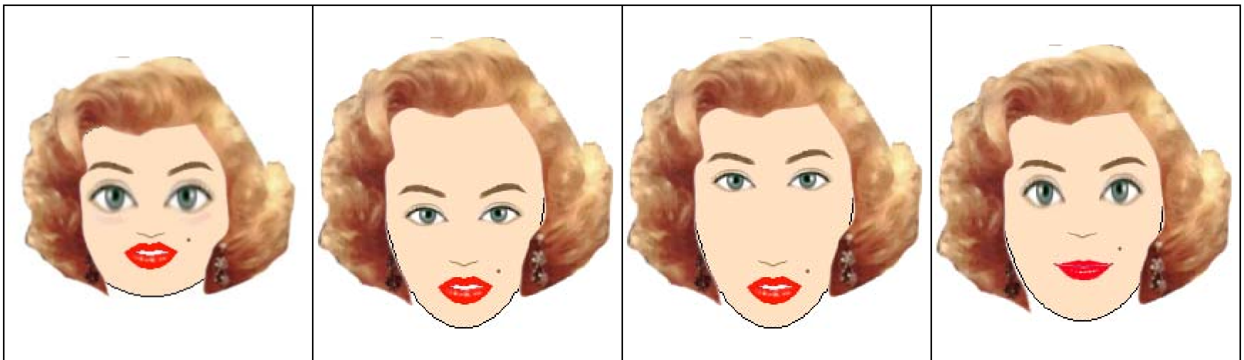


Figure 6(b) : Examples of different hair styles of cartoon face



13221 (minimum error)	12221 shorten chin	11221 short forehead and chin	11221 shorten chin and centralize sense organs

Figure 6(c) : Same facial model, but different aspect ratios for each segment



13221 exaggerate eye feature	12221 centralize cheek and chin segment	11221 horse-faced	23221 different expression

Figure 6(d) : different aspect ratios and exaggerated cartoon faces

Figure 6 : Examples of various cartoon faces for actress Marilyn Monroe(1926-1962)

6. Conclusions

In this paper, a 2D caricature face generating system is introduced, and the facial feature extraction problems and matching techniques in transformed feature space have been presented and demonstrated as well. This paper shows that face contour, aspect ratio, and the location of selected control feature points for each facial segment play an important role to distinguish individual face. A 2D caricature face possessing original face characteristics can be utilized in the virtual Internet real-time applications, such as Internet games, net-meeting, distance learning, web advertisement, and so on. Due to the advantageous features of privacy, security, amusement and compact file size, the 2D caricature faces become more noticeable. Furthermore, it is a lot of fun and becomes possible that we can create our own caricature faces in different exaggerating expression or hair styles without any cartoonist help. .

7. Acknowledgement

We thank Fu-Sheng Chang, Yuan-Shu Hsiao, and Ching-Hsiang Chiang at Dept. of Computer Science, National Taiwan Ocean University for their contributions to the creation of facial database and for many useful comments on algorithms of feature extraction.

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