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A New Algorithm to Classify Face Emotions through Eye and Lip Features by Using Particle Swarm Optimization

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Abstract. Facial expressions give important clues about emotions. Computer systems based on affective interaction could play an important role in the next generation of biometric surveillance systems. Face emotion recognition is one of the main applications of computer vision that is widely attended in recent years and can be used in areas of security, entertainment and human machine interface (HMI). The research of emotion recognition consists of facial expressions, vocal, gesture and physiology signal recognition and etc. In this paper a new algorithm based on a set of images to face emotion recognition has been proposed. This process involves three stages: pre-processing, feature extraction and classification. Firstly a series of pre-processing tasks such as adjusting contrast, filtering, skin color segmentation and edge detection are done. One of the important tasks at this stage after pre- processing is to extract features. To extract features with high speed projection profile is used. Second particle swarm optimization (PSO) is used to optimize eye and lip ellipse characteristics. Finally in the third stage, with using the features obtained of the optimal ellipse eye and lip, a person emotion according to experimental results and emotions represented by Ekman (sadness, angry, joy, fear, disgust and surprise without consider natural emotion) is classified. The obtained results show that the success rate and running speed in face emotion recognition in comparison with previous methods has better performance.

Keywords. Pre-processing, Feature extraction, Projection profile, Eye and lip ellipse, Emotions classification, Particle swarm optimization algorithm, Emotion recognition

1. Introduction

There are many ways that humans can express their emotions. The most natural way to express emotions is using facial expressions. A human can express his/her emotion through lip and eye. A category of emotions which universally developed by Ekmen are: sadness, angry, joy, fear, disgust and surprise without consider natural emotion. The main goal of this paper is to introduce a method to assign an image to one of these categories by using pso algorithm. In this study for the validity of research a collection of Indian images including 350 images in 7 emotions have been used. This method consists of mainly three parts. The first part describes various stages in image processing include preprocessing, filtering, edge detection and projection profile is used to extract features. The second part discusses a pso- based approach to optimize the eye and lip ellipse characteristics. In the third part we using of the eye and lip optimal parameters to classify the emotions. The general process for emotion recognition is shown in Fig1. The rest of this paper organized as follows. Section 2 is an overview of related works. The method with pso algorithm is described in section 3. Efficiency analysis and results of the method is discussed in section 4 and section 5 contains conclusion.

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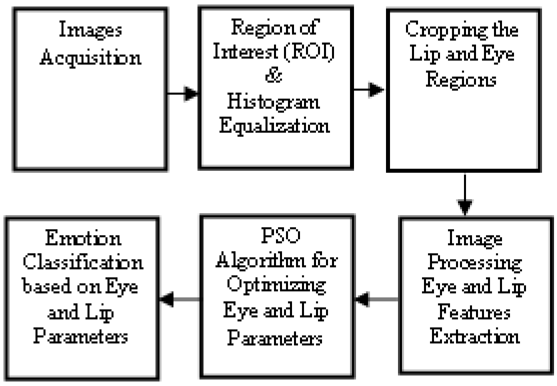

Fig.1. emotion recognition process

2. Related works

Facial expressions give important clues about emotions. Therefore, several approaches have been proposed to classify human affective states. The features used are typically based on local spatial position or displacement of specific points and regions of the face, unlike the approaches based on audio, which use global statistics of the acoustic features. For a complete review of recent emotion recognition systems based on facial expression the readers are referred to [1]. Mase proposed an emotion recognition system that uses the major directions of specific facial muscles [2]. With 11 windows manually located in the face, the muscle movements were extracted by the use of optical flow. For classification, K-nearest neighbor rule was used, with an accuracy of 80% with four emotions: happiness, anger, disgust and surprise. Yacoob et al. proposed a similar method [3]. Instead of using facial muscle actions, they built a dictionary to convert motions associated with edge of the mouth, eyes and eyebrows, into a linguistic, per- frame, mid-level representation. They classified the six basic emotions by the used of a rule-based system with 88% of accuracy. Black et al. used parametric models to extract the shape and movements of the mouse, eye and eyebrows [4]. They also built a mid- and high-level representation of facial actions by using a similar approach employed in [3], with 89% of accuracy. Tian et al. attempted to recognize Actions Units (AU), developed by Ekman and Friesen in 1978 [5], using permanent and transient facial features such as lip, nasolabial furrow and wrinkles [6]. Geometrical models were used to locate the shapes and appearances of these features. They achieved a 96% of accuracy. Essa et al. developed a system that quantified facial movements based on parametric models of independent facial muscle groups [7]. They modeled the face by the use of an optical flow method coupled with geometric, physical and motion-based dynamic models. They generated spatial-temporal templates that were used for emotion recognition. Without considering sadness that was not included in their work, a recognition accuracy rate of 98% was achieved. A method that extracts region of eye and lip of facial image by genetic algorithm has been suggested recently [8]. The obtained results show that the success rate and running speed in face emotion recognition using eye and lip by particles swarm optimization algorithm in comparison with the genetic algorithm has better performance.

3. The proposed method

The main goal of this paper is to design a method with a new optimization algorithm to emotion recognition. As the first step in image processing, for skin color segmentation, first we contrast the image. A histogram equalization method has been applied. This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. The histogram equalized image is filtered using average and median filters in order to make the image smoother. We have to find the largest connected region. Then we have to check the probability to become a face of the largest connected region. If the largest connected region has the probability to become a face, then it will accept as the largest connected region. If the largest connected regions height & width is larger or equal than 50 and the ratio of height/width is between 1 to 2, then it may be face. For face detection, first we convert binary image from rgb image. For converting binary image, we calculate the average value of rgb for each pixel and if the average value is below than 110, we replace it by black pixel and otherwise we replace it by white pixel. By this method, we get a binary image from rgb image. Then, we try to find the forehead from the binary image. We start scan from the middle of the image, then want to find a continuous white pixels after a continuous black pixel. Then we want to find the maximum width of the white pixel by searching vertical both left and right site. Then, if the new width is smaller half of the previous maximum width, then we break the scan because if we reach the eyebrow then this situation will arise. Then we cut the face from the starting position of the forehead and its high will be 1.5 multiply of its width. X will be equal to the maximum width of the forehead. Then we will have an image which will contain only eyes, nose and lip. Then we will cut the rgb image according to the binary image. For eyes detection, we convert the rgb face to the binary face. Now, we consider the face width by W. We scan from the W/4 to (W-W/4) to find the middle position of the two eyes. The highest white continuous pixel along the height between the ranges is the middle position of the two eyes. Then we find the starting high or upper position of the two eyebrows by searching vertical. For left eye, we search w/8 to mid and for right eye we search mid to w – w/8. Here w is the width of the image and mid is the middle position of the two eyes. There may be some white pixels between the eyebrow and the eye. To make the eyebrow and eye connected, we place some continuous black pixels vertically from eyebrow to the eye. For left eye, the vertical black pixel-lines are placed in between mid/2 to mid/4 and for right eye the lines are in between mid+(w-mid)/ 4 to mid+3*(w-mid)/ 4 and height of the black pixel-lines are from the eyebrow starting height to (h- eyebrow starting position)/4. Here w is the width of the image and mid is the middle position of the two eyes and h is the height of the image. Then we find the lower position of the two eyes by searching black pixel vertically. For left eye, we search from the mid/4 to mid - mid/4 width. And for right eye, we search mid + (w-mid)/ 4 to mid+3*(w- mid)/ 4 width from image lower end to starting position of the eyebrow. Then we find the right side of the left eye by searching black pixel horizontally from the mid position to the starting position of black pixels in between the upper position and lower position of the left eye. And left side for right eye we search mid to the starting position of black pixels in between the upper position and lower position of right eye. The left side of the left eye is the starting width of the image and the right side of the right eye is the ending width of the image. Then we cut the upper position, lower position, left side and the right side of the two eyes from the rgb image. For lip detection, we determine the lip box. And we consider that lip must be inside the lip box. So, first we determine the distance between the forehead and eyes. Then we add the distance with the lower height of the eye to determine the upper height of the box which will contain the lip. Now, the starting point of the box will be the ¼ position of the left eye box and ending point will be the ¾ position of the right eye box. And the ending height of the box will be the lower end of the face image. So, this box will contain only lip and may some part of the nose. Then we will cut the rgb image according the box. Finally, sobel edge detection method due to the high speed and small volume of calculations is applied to the eyes and lip image. The sobel edge detection region of lip and eye region are shown in Fig 2 and Fig3.

Fig. 2. The surprise emotion

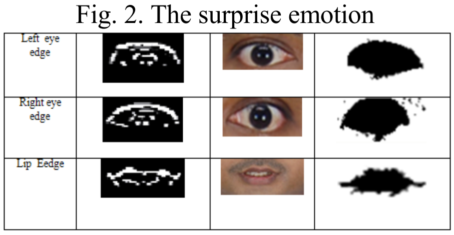

Fig.3. Sobel edge detected

3.1. Feature Extraction

Feature extraction method is associated with the row-sum and column-sum of white pixels of edge identified image. The pattern of row-sum (Mh) along the column and the pattern of column-sum (Mv) along the row of white pixels are defined as the feature of each region. These patterns are known as projection profiles. Let f (m, n) represents a binary image of m rows and n columns. Then the vertical profile is defined as the sum of white pixels of each column perpendicular to the x-axis which is represented by the vector Mv of size n by (1).

$$M_{vj} = \sum_{i=1}^{m} f(i,j) \qquad j = 1,2,3,\ldots \tag{1}$$

The horizontal profile is the sum of white pixels of each row perpendicular to the y-axis which is represented by the vector M_h of size m is calculated by (2).

$$M_{hi} = \sum_{j=1}^{m} f(i,j) \qquad i = 1,2,3,\ldots \tag{2}$$

The human eye shape is more like an ellipse (we call this as a regular ellipse), as shown in Fig4. The minor axis is a feature of the eye that varies for each emotion. The major axis of the eye is more or less fixed for a particular person in varied emotions. The ellipse is parameterized by its minor and major axes, respectively, as "2a" (fixed) and "2b" (to be computed) is described by (3).

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \tag{3}$$

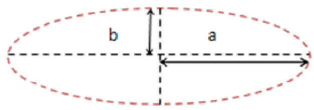

Fig.4. the regular ellipse

The shape of human lip is towards a combination of two ellipses which is called an irregular ellipse, as shown in Fig5. The word 'irregular' means that the ellipse has two different minor axes wherein the major axes remains the same. The edge detected lip image is considered as an irregular ellipse. Lengths of minor axes of the lip feature for each emotion are computed. The major axis is "2a" (considered to be fix) and two minor axes are "2b1" and "2b2" (to be computed). The suitable values to b1 and b2 are substituted for top and bottom portions respectively. Emotional state on an Image strongly depends on facial expression b1, b2 as expression of lip and b as expression of eye. In the next section pso algorithm adopted to optimize these expressions.

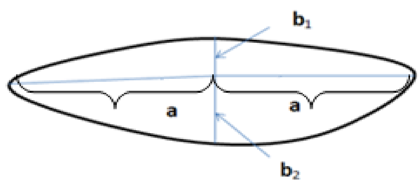

Fig.5. the irregular ellipse

3.2. Particle Swarm Optimization

As stated before, PSO simulates the behaviors of bird flocking. Suppose the following scenario: a group of birds are randomly searching food in an area. There is only one piece of food in the area being searched. All the birds do not know where the food is. But they know how far the food is in each iteration. So what's the best strategy to find the food? The effective one is to follow the bird which is nearest to the food. PSO learned from the scenario and used it to solve the optimization problems. In PSO, each single solution is a "bird" in the search space. We call it "particle". All of particles have fitness values which are evaluated by the fitness function to be optimized, and have velocities which direct the flying of the particles. The particles fly through the problem space by following the current optimum particles. PSO is initialized with a group of random particles (solutions) and then searches for optimal by updating generations. In every iteration, each particle is updated by following two "best" values. The first one is the best solution (fitness) it has achieved so far. (The fitness value is also stored.) This value is called pbest. Another "best" value that is tracked by the particle swarm optimization is the best value, obtained so far by any particle in the population. This best value is a global best and called gbest. When a particle takes part of the population as its topological neighbors, the best value is a local best and is called lbest. After finding the two best values, the particle updates its velocity and positions with following equation (4) and (5).

$$v[] = v[] + c_1 * rand() * (pbest[] - present[]) + c_2 * rand() * (gbest[] - present[]) \quad (4)$$

$$present[] = present[] + v[] \quad (5)$$

v [] is the particle velocity, present [] is the current particle (solution). pbest [] and gbest [] are defined as stated before. Rand () is a random number between (0, 1). c1, c2 are learning factors. Usually $c_1 = c_2 = 2$. Algorithm parameters are shown in Table 1.

Tab.1 parameter settings for PSO processing

Description	Parameter
(x, x_1, x_2)	Particle
200	number of particles
3	Dimension of particles
It is also determined by the problem to be optimized. $X_1>=0$ and $X_2<=0$	Range of particles
It determines the maximum change one particle can take during one iteration.	$V_{max}=20$
Usually c1 equals to c2 and ranges from [0, 2].	Learning factors
The maximum number of iterations the PSO execute and the minimum error requirement.(one miss-classified)	stop condition
local version is a little bit slower but not easy to be trapped into local optimum.(refine the search)	Version
$W_{max}=0.9$, $W_{min}=0.4$	inertia weight
500	max iteration number
W_{max}-((W_{max}- W_{min})/ max iteration)* iteration	W(iteration)

4. Experimental results

In this study on an Indian subject, seven emotions and 350 images were examined (website address for displaying images is: http://up7.iranblog.com/images/oypv46b427fvxdpnuoi6.pdf). The eye and lip features have been given as input to the PSO algorithm to find the optimized values (ellipse optimum). Optimization process was repeated 20 times for each emotion. Thereupon optimal parameters (x, x_1, x_2) come from of optimal ellipsoid axes. In Table 2 manual measured parameters from 350 images and PSO optimized parameters (The mean of the parameters) are shown. Table 3 shows the same calculation with the genetic algorithm. By comparing Table 2 and Table 3 we observe that the success rate and running speed in PSO has better performance.

Tab.2 Manual and PSO optimal measured parameters

Emotion	**Manually Computed Mean Value (in pixels)**			**Optimized Mean Value by PSO (in pixels)**			**50 Images For each emotion**	**Duration of Emotion Recognition (sec)**
	b_1	b_2	b	x_1	x_2	x	**Success Rate**	**Mean Time**
Natural	38	41	21	36.8165	40.2366	20.9852	91%	45
Fear	25	41	16	24.2525	40.6355	14.6565	88%	38
Happy	25	48	16	23.9612	47.2256	14.6353	93%	49
Sad	33	34	19	32.1464	33.5598	18.9751	86%	48
Angry	25	34	16	24.1256	32.2684	15.6521	92%	47
Dislike	35	29	13	34.2565	28.2255	12.9850	89%	36
Surprise	43	57	17	42.9680	55.2685	15.1451	92%	49

Table3. Manual and genetic algorithm optimal measured parameters

Emotion	Manually Computed Mean Value (in pixels)			Optimized Mean Value by GA (in pixels)			50 Images For each emotion	Duration of Emotion Recognition (sec)
	b_1	b_2	b	x_1	x_2	x	**Success Rate**	**Mean** Time
Natural	38	41	21	35.2644	38.2531	19.6188	62%	114
Fear	25	41	16	22.0287	38.9529	13.7024	68%	170
Happy	25	48	16	23.5929	45.4742	13.0393	75%	156
Sad	33	34	19	31.9104	31.4511	16.9633	61%	158
Angry	25	34	16	22.2781	33.8381	13.4120	69%	120
Dislike	35	29	13	32.3409	26.6276	10.8353	64%	140
Surprise	43	57	17	41.6892	54.0180	14.0701	69%	185

5. Conclusion

Current methods for emotion recognition are: facial expressions, vocal, gesture, physiology signal recognition and etc. In related works several methods were investigated for the facial expressions. In this paper we propose a method based on facial expressions with a new optimization algorithm. Firstly a series of pre- processing tasks such as adjusting contrast, filtering, skin colour segmentation and edge detection are done. One of the important tasks at this stage after pre- processing is to extract features. To extract features with high speed projection profile is used. Second eye and lip features are given as input to the PSO to compute the optimized values of b, b_1, and b2. Finally in the third stage, with using the features obtained of the optimal ellipse eye and lip, a person emotion according to results Table2 and emotions represented by Ekman (sadness, angry, joy, fear, disgust and surprise without consider natural emotion) is classified. Observation of various emotions leads to a unique characteristic of eye and lip. They are exhibit the eye and lip ellipses with different parameters in each emotion. On average, by comparing PSO and genetic algorithm for this problem we observe that the success rate and running speed in PSO has better performance.

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