Facial Recognition under Expression Variations

Mutasem K. Alsmadi

Department of MIS, Collage of Applied Studies and Community Service, University of Dammam, Tel: 00966545526901 ; email: mksalsmadi@gmail.com.

Abstract:*Researchers in different fields such as image processing, neural sciences, computer programs and psychophysics have investigated number of problems related to facial recognition by machines and humans since 1975. Automatic recognition of the human emotions using facial expression is an important, but difficult problem. This study introduces a novel and automatic approach to analyze and recognize human facial expressions and emotions using a metaheuristic algorithm, which hybridizes iterated local search and genetic algorithms with back-propagation algorithm (ILSGA-BP). Back-propagation algorithm (BP) was used to train and test the extracted features from the extracted right eye, left eye and mouth using radial curves and Cubic Bézier curves, Metaheuristic algorithm (MA) was used to enhance and optimize the initial weights of the traditional back-propagation algorithm. FEEDTUM facial expression database was used in this study for training and testing processes with seven different emotions namely; surprise, happiness, disgust, neutral, fear, sadness and anger. A comparison of the results obtained using the extracted features from the radial curves, Cubic Bézier curves and the combination of them experiments were conducted. The comparison shows the superiority of the combination of the radial curves and the Cubic Bézier curves with percentage ranges between 87% and 97% over the radial curves alone with a percentage ranges between 80% and 97% and over the Cubic Bézier curves with a percentage ranges between 83% and 97%. Moreover, based on the extracted features using the radial curves, Cubic Bézier curves and the combination of them, the experimental results show that the proposed ILSGA-BP algorithm outperformed the BP algorithm with overall accuracy 88%, 89% and 93.4% respectively, compared to 83%, 82% and 85% respectively using BP algorithm.*

Keywords:*Face Recognition, Cubic Bézier Curves, Radial Curves, Features Extraction, Metaheuristic algorithm and Back-Propagation Algorithm.*

1. Introduction

In human interaction, diverse ways for self-expression are used, such as body gestures, facial expression and speech. Where speaking is connected with some facial movements such as eyebrow-raise, cheeks-movements and eye-contact [1, 2]. The face expressions are connected with multiple sources as shown in figure 1. Psychologically, any change in the face features is connected with emotional changes and this will help in the human communication especially when the verbal communication is not enough or very difficult to be achieved [2].

Comparing unknown images with databases of known face images are used for face recognition process which is performed using computer application for face identification. Many disciplines are involved, such as image processing, pattern recognition, computer graphics, computer vision and machine learning. From 1975 until now, researchers in several fields such as engineering, neural sciences and psychophysics, image analysis and computer vision have investigated and tackled number of difficulties regarding to face recognition by machines and humans [4].

Boughrara et al. (2012) proposed a 2D face recognition approach with different expressions using the local features matching and perceived facial image, they used a new biological vision-based facial description which is called Perceived Facial Images (PFIs), originally this approach was used for 3D face recognition, it aims to give a graphical representation simulates the visual perception by human. This method was robust in affining the facial expressions and lighting transformations.

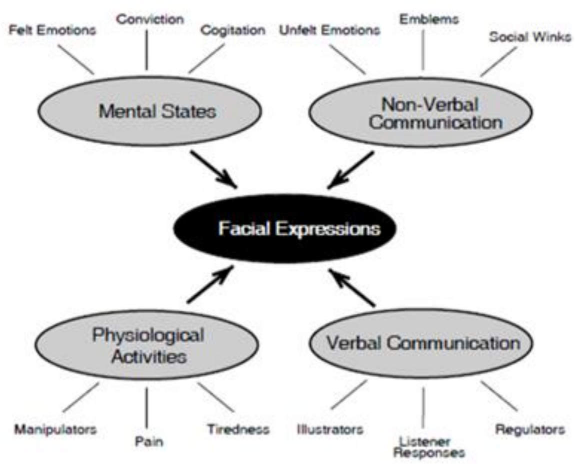


Figure 1. Some facial expressions sources [2, 3].

Das in [6] proposed an individual independent real-time facial expression recognition method using Feature-based geometrical approach. Geometry of the face is extracted by the adapted active shape model (ASM). Every face geometry part is efficiently represented using Census Transformation histogram of features. The face expressions are classified using support vector machine classifier and exponential chi-square weighted merging kernel.This proposed approach was tested on JAFFE database, the results show that this approach can be applied on real-time facial expression experiments and produces good accuracy results.

An approach was proposed by [7] for facial expression recognition using non-negative least squares sparse coding. This method was utilized to build a classifier for facial expressions. In order to test the performance of the proposed approach, the raw pixels and the local binary patterns are extracted to represent the facial features. They also used the JAFFE database for testing the proposed method and the results show that NNLS approach obtained better accuracy rates compared with other facial expression recognition methods.

Drira et al. (2013) proposed a new geometric framework in order to analyze 3D faces, based on specific aims of matching, comparing and averaging of faces shapes. The authors used the radial curves arising from the nose tip. Thus; the obtained curves were used to develop a Riemannian framework using elastic shape analysis for exploring full shapes of facial surfaces. The proposed method elastic Riemannian metric has been used for measuring facial distortions and it was robust to many challenges such as large pose variations, hair, different and large facial expressions and missing parts. The proposed framework shows promising results for both theoretical and empirical perspectives. Where the proposed framework enable the formal statistical inferences, and the obtained results exceeded or matched the recent methodologies using three noticeable databases: Bosphorus, FRGCv2 and GavabDB.

Bennamoun and El-Sallam (2013) developed a novel approach for 3D face recognition based on some low-level geometric features which were collected and extracted from the nose and eyes-forehead areas. These areas were used because they are less subjective to distortions that may be produced due to the facial expressions. The extracted features were used to compute a region-based histogram descriptor and the Support Vector Machine (SVM) was used as a classifier, the experimental results show the success of the feature-level fusion scheme compared with score-level fusion in obtaining higher verification rates.

Kandemir and Özmen (2013) analyzed 2D facial images with different expressions such as anger, sadness, surprise, fear, smile, neutral and disgust. The authors have used Viola-Jones for face detector and AdaBoost algorithm has been used to locate and determine the face location. In order to find and extract mouth and eyes regions Haar filters as well as the ratios of facial geometric were used to decrease the mouth and eyes detection error. In their work, Cubic Bézier curves were used in recognizing and determining the facial expressions. FEEDTUM database has been used in the training and testing processes to validate the proposed methods. The experimental results show that the success rates of the proposed methods ranged between 60% and 97%.

A 2D recognition system for human expressions was proposed by [10]. The proposed system works based on studying the important keys in the facial regions using principal component analysis (PCA) and neural networks (NNs). PCA was used to decrease elements number in the features vectors. NNs were used because they were adapted to specific classification problems, it permit higher flexibility in the training process. FEEDTUM database has been used to train and test the proposed methods. The obtained results show high recognition accuracy range (46% - 80%).

Genetic algorithm (GA) is a heuristic algorithm, it is a population based approach, GA simulates the process of selection in the nature, and it is utilized to generate new solutions to the complicated problems by taking sample solutions from a population of solutions. It contains three major steps which are selection, crossover, and mutation. Selection mechanism selects two solutions and recombines them. Other types of selection is recommended by Michalewicz in [11] such as Roulette Wheel Selection, Truncation Selection, and Tournament Selection. The crossover performs mating procedure, this procedure finds new solutions (higher fitness value) from the search space. Mutation is the local search process that finds neighborhood solutions then disturbs the population to improve the search space quality so generating solutions with higher fitness values [12].

Iterated local search is very simple, effective, robust, and easy to implement algorithm, it performs a local search in a partial sub-space as an alternative to the search in the whole solutions search space. It aims to find a local optimum solution, then it performs solutions perturbation and restarts the local search. The main drawback of the local search is being trapped in the local optima, iterated local search avoids this problem by disturbing the local optimum solutions, and using them to generate new solutions randomly. Refer to [13] for more details about ILS algorithm.

The main contributions of this work is to propose novel automatic geometric approaches for analyzing and recognizing human face expressions based on some extracted features using radial curves and Cubic Bézier curves, and to enhance and optimize the initial weights of the traditional back-propagation algorithm using the proposed Metaheuristic algorithm (iterated local search and genetic algorithms).

In this paper, Section 2 describes the material and methods used in this work. Section 3 discusses the proposed ISLGA-BP algorithm. Section 4 explains the experimental result. Section 5 discusses the obtained results. Finally, the conclusions are Section 6.

2. Material and Method

Since the dynamic facial images can offer more information (features) about facial expression compared with single facial static image, sequence of dynamic facial images are the inputs of the proposed automatic facial recognition with different expressions [2]. The proposed method consists of six steps, namely; 1. Face detection, 2. Face selection, 3. Features extraction, 4. Automated information extraction using radial curve and Cubic Bézier curves, 5. Face expression recognition using the proposed ILSGA-BP algorithm. Figure 2 shows the main steps of the proposed methods.

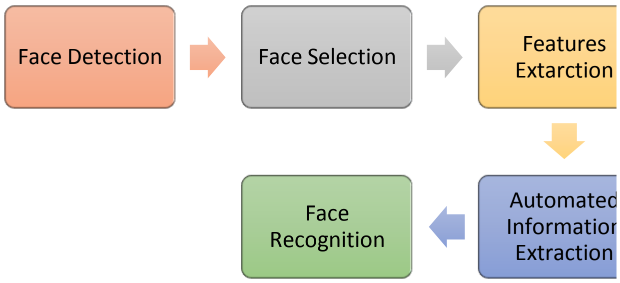


Figure 2. The main steps of the proposed methods.

2.1 Face Detection

Face detection is an important step in the facial recognition process which is important to be done in an automatic and dynamic way [2, 14, 15]. Skin color is widely used for differentiating human and nonhuman faces. The main idea of the skin color segmentation process is classifying the input image pixels into skin and non-skin pixels. In order to achieve successful skin color segmentation process, we applied the skin color reference map in the YCrCb space.

The skin color area is recognized by existence of set of chrominance such as *Cb* and *Cr*, values are distributed in the color space of *YCrCb*. R_{Cb} and R_{CR} denotes the ranges of *Cb* and *Cr* values that are related to the color of skin, R_{Cb} and R_{Cr} describe the skin-color reference map for any person image. This work, used the reported method by [16-18] which was developed by Chai and Ngan in [19], which proved by experiments that the value of R_{Cr} between 133 and 137 and R_{Cb} between 77 and 127 are related to the skin pixels. These values were very robust in recognizing skin region in different kinds of skin color. Moreover, the justification for using similar *Cb* and Cr distributions for all races skin color is that the skin color differences perceived by the viewer are generally due to the skin fairness or darkness; which are characterized by the color brightness variations, which are directed by Y not *Cb* and *Cr*.

Using the color information from the input image, the skin color segmentation process can be established where it requires only the chrominance component of the image [19]. Considering an image with size of *M x N*, the dimension of Cb and Cr is *M/2 x N/2* the color segmentation step output is a bitmap image with a size of *M/2 x N/2*, it is described as follows [19]:

$$O_1(x,y) = \begin{cases} 0, & if\ [C_r(x,y) \in R_{Cr}] \cap [Cb(x,y) \in R_{Cb}] \\ 1, & otherwise \end{cases}$$

Where *y=0,.....N/2-1 and x=0,.....,M/2-1*. Output pixel value at the point *(x,y)* is then identified as skin color if both of *Cb* and *Cr* is in the range of their R_{Cb} and R_{Cr} respectively and is set to 0. Else the pixels is categorized into non-skin pixels and set to 1. Figure 3 and 4 show the original image, skin and non-skin pixels respectively.

Figure 3. The original image.

Figure 4. Skin and non-skin pixels illustration.

2.2 Face Selection

After completing the face detection process, Face selection will be started. Where, in this research we use the distance measurements to locate and extract the face area based on the skin and non-skin pixels. The following steps were involved in the face extraction process:

1. Consider *H* and *W* as the height and width of skin and non-skin pixels.
2. At the position *(0, H/2)* read the pixel.
3. Horizontally, move a distance *D1= W/6* in order to obtain the start boundary pixel of skin area.
4. Move a distance *D2= H/6* from the pixel position *(W/6, H/2)* in up direction. Do the same downward and localize the points *X1, X2*.
5. Move a distance *D3=W/3* from the point X1 and localize the point *X3*. Do the same from *X2* and localize the point *X4*.
6. Extract the square image.

Once the face selection process is completed, the pixels of the black region (face region) are filled with skin color as shown in figure 5.

Figure 5. Face selection with skin color and dimension enhancement.

2.3 Extraction of face features

Human face consists of different part such as chine, mouth, eyes and nose. These parts are different in the shape, structure and size [20]. The differences in the organs' size, shape and structure cause the difference between faces in many ways. Based on the previous studies, extracting the shape of the eyes and mouth is considered as a significant way to distinguish between different faces expression using the scale and distance of these parts (organs) [21]. The steps of face feature extraction in this work are as following:

1. Consider *H* and *W* are the height and width of face image as shown in figure 6.
2. Divide the height by four *(H/4).*
3. Skip the first upper quarter, because it doesn't contain any significant part.
4. Divide the second upper quarter vertically into two parts, in order to obtain the eyes shape and size.
5. Skip the third quarter, because it doesn't contain any significant part.
6. Lower quarter was used to extract the mouth size and shape.

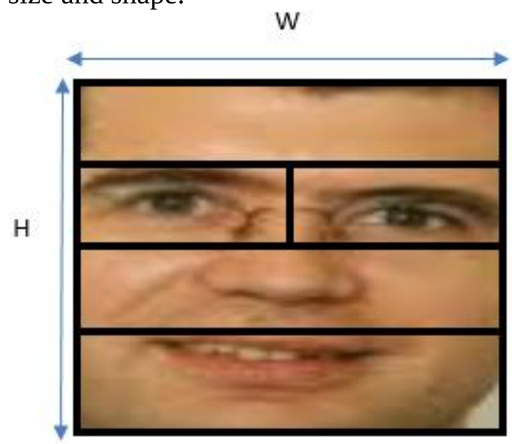


Figure 6. Eyes and mouth features extraction.

Figure 7 below shows the extracted right eye, left eye and mouth using automatic distance measurements. In the next sections, radial curve and Cubic Bezier curve were applied in order to automatically extract the curve information (features), then the extracted features will be matched and recognized using the developed ILSGA-BP algorithm, as well as comparison study were conducted between the obtained results using radial curve and Cubic Bezier curve.

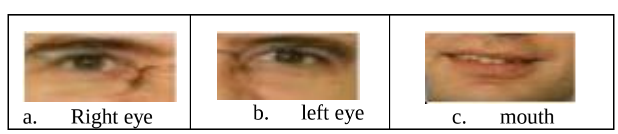


Figure 7. The extracted right eye, left eye and mouth.

2.4 Automated Features Extraction of Radial Curves and Cubic Bezier curve

2.4.1 Radial Curves

An indexed collection is used to represent each of the extracted right eye, left eye and mouth using radial curves that are distinct as follows.

Using the image processing techniques, this work successfully determined the start point (P0) and the end point (P3) of the right eye, left eye and mouth using skin color and non-skin color. Where this work assign the value 0 to all the pixels inside and the value 1 to all the pixels outside the eye. The same procedure was applied on the extracted mouth. Then the following equation was used to determine the mid-point (Pi) between the P0 and P3 (see figure 8).

$$P_i = \left((x_1 + x_2)/2, \left((y_1 + y_2)/2\right)\right)$$

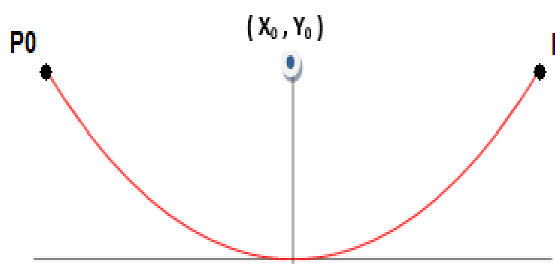


Figure 8. The start point, end point and mid-point.

The equations of the curve parameters $(f(t), g(t))$ with radial point (x_0, y_0) and parameterized by a variable *t* as follows [22]:

$$x = x_0 - \frac{g'(f'^2 + g'^2)}{f'g'' - f''g'}$$

$$y = y_0 + \frac{f'(f'^2 + g'^2)}{f'g'' - f''g'}$$

After, some mathematical calculations with respect to the parameter *t*, the radial catenary curve are [23]:

$$x = t$$

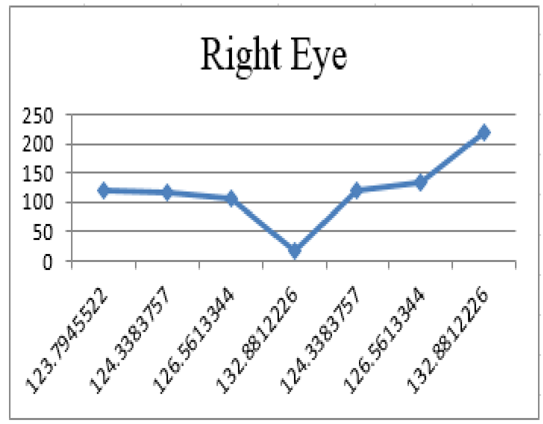
$$y = cosh\, t$$

with radiant point (x_0, y_0) as follows [23]:

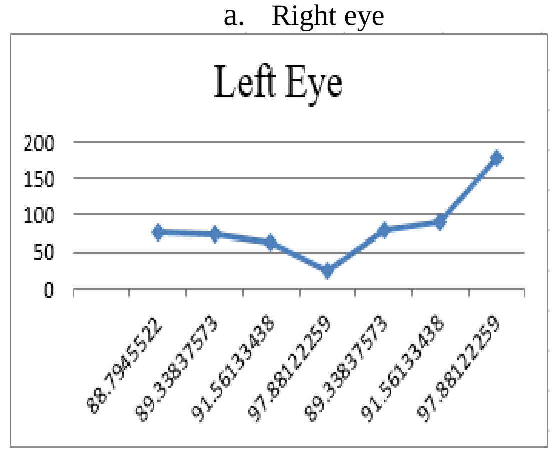
$$x_r = x_0 - cosh\, t\, sinh\, t$$

$$y_r = y_0 + cosh\, t$$

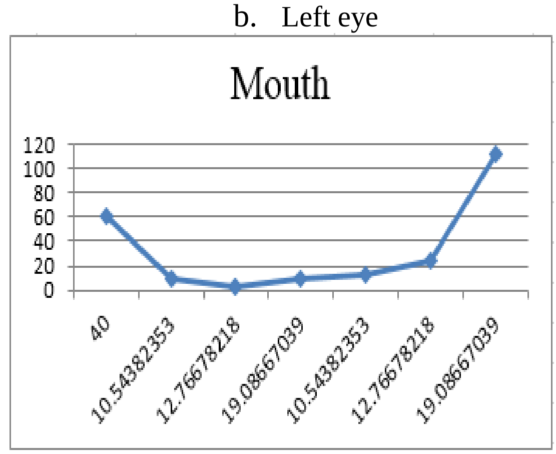
figure 9 shows an example of the obtained radial curve information based on the extracted right eye, left eye and mouth, where the values of the variable *t* that were used in this work are [-5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5].



a. Right eye



b. Left eye



c. Mouth

Figure 9. Example on the obtained radial curve information based on the extracted right eye, left eye and mouth.

2.4.2 Cubic Bezier curve

Bézier curves are the most essential and important curves that were used widely in many computer and image processing application for many purposes such as object representation, curve fitting, interpolation and approximation [2, 14, 20]. Bézier curve could be represented using the most effective corners of polygon [2].

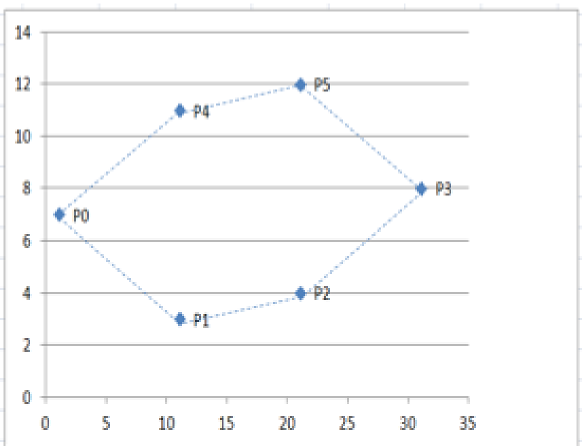


Figure 10. The four control points of the Cubic Bézier curves.

Multiple control points are used to describe Bézier curves comprehensively. But increasing the number of control points will increase the computational complexity, and increasing polygon degree will increase the difficulty of computational process [2]. To avoid these problems, a Cubic Bézier curves with four control points are used (see figure 10), these points have been used in this work in order to determine facial expression.

Cubic Bézier curves is drawn based on the extracted right eye, left eye and mouth as shown in figure 11. The equation of the Cubic Bézier curves is given as below [24]:

$$B(t) = (1-t)^3 P_0 + 3(1-t)^2 t P_1 + 3(1-t)t^2 P_2 + t^3 P_3 , t \in [0,1]$$

Figure 11. The drawn Cubic Bézier curves based on the extracted right eye, left eye and mouth respectively.

2.5 Feedtum Database

In this work, the FEEDTUM database was used [25], because of the manual annotation of the basic facial expressions. This database contains 9 female and 10 male images of European people in the age between 20 and 35 years old. These images have a size of 320*240 and taken as sequence of 5700 images of the 19 subjects, for each expression there are three sequences showing the stages of the development of the expression. Each individual has seven basic emotions, namely; surprise, happiness, disgust, neutral, fear, sadness and anger. Figure 12 shows an example of how the image sequence built the facial expression data.

In this work, 700 images from the FEEDTUM database have been used, for each face expression 100 images were selected. We divided the selected images as the following: 30 images for testing and 70 images for training processes for each expression.

3. The proposed ILSGA-BP algorithm

A multilayer feed forward NN with Back-propagation algorithm was used in this study [26, 27]. Back-propagation algorithm was used for training and testing the extracted features from the right eye, left eye and mouth using radial curves and Cubic Bézier curves.

Figure 12. An example of how the image sequence built the facial expression data [28].

The proposed model consists of three layers, namely; input layer, hidden layer and output layer. The number of neurons in the input layer equals the number of related extracted features (see table 1). 45 neurons were used for hidden layers, 7 neurons were used for the output layer since the aim of this work is to recognize 7 facial expression (see table 2). Figure 13 shows the proposed NN model with input, hidden and output layers.

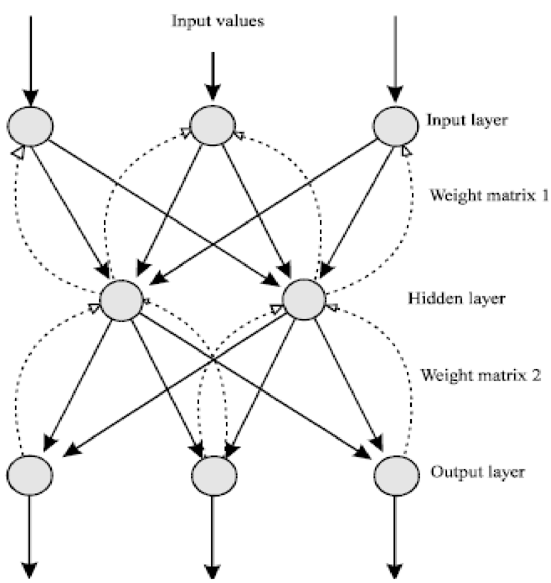


Figure 13. The proposed NN model with input, hidden and output layers [20].

3.1 Metaheuristic algorithm

Figure 14 shows the diagram of the proposed ILSGA-BP algorithm. This model utilized multilayer feed forward NN as a hybrid learning algorithm using MA for network parameters (weights) optimization. The network parameters are encoded to form a chromosome, this chromosome is tuned by MA. Then, the role of BP algorithm is to train the network. The local search algorithm when inserted in to the GA enhances the exploitation process rather than the exploration process [29]. Table 3 shows the parameters of the used MA algorithm.

The process of the proposed hybrid algorithm is indicted as follows:

1. Initialization: Each solution in the search space is represented by a binary number, the chromosome is denoted by a real value (fraction number) in the weight matrix. The fraction number is represented in the gene inside the chromosome by a binary string.

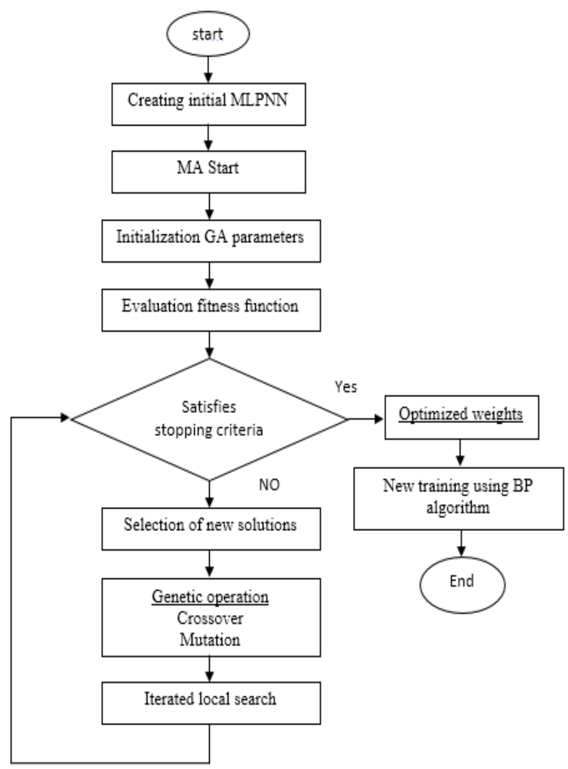


Figure 14. The diagram of the proposed ILSGA-BP algorithm.

2. Selection: The main idea of the selection is to select the chromosomes with the highest fitness value for reproduction in the population space to generate new solutions

with higher fitness values. In this work, roulette wheel selection is utilized as a selection mechanism [30].

3. Crossover: Crossover is employed to combine the information from two parent chromosomes to generate new solutions (chromosomes) this operator cuts the two parents at random points then exchanges the resulting segments [12].
4. Mutation: Mutation is used as a local search operator for maintaining the diversity of the newly generated generations [12], it works by exchanging one bit in the generated chromosome at a predetermined point, this operation helps to avoid stopping or slowing down the evaluation procedure.
5. Fitness Function: The main role of the fitness function is to evaluate the candidate solutions quality, it is dependent on the problem domain. This work used the Variance Account Function (VAF) which is calculated as follows [31]:

$$V = 1 - \frac{variance\ (y - y\_test)}{variance\ (y)}$$

The real output is denoted by y, y_test denotes the model estimated output, and VAF is computed for the two signals to result of the output V. The VAF is used to evaluate correctness of the model, through comparing actual output with the expected model output.

4. Experimental results

Different facial expression results were obtained using the proposed ILSGA-BP algorithm based on the extracted features from the extracted right eye, left eye and mouth, where these features were extracted using radial and Cubic Bézier curves. In this study, four experiments were conducted as following:

1. Experiment based on the extracted features using radial curves.
2. Experiment based on the extracted features using Cubic Bézier curves.

Table 1. The number of extracted features using the proposed methods.

Methods	Number of extracted features
Extracted features using radial curves	23
Extracted features using Cubic Bézier curves	23
Extracted features using radial curves and Cubic Bézier curves	46

Table 2. The number of neurons for every layer in the proposed neural network and the number of features extracted.

Classifiers	Neurons number	
	Hidden layer	**Output layer**
BP Algorithm	45	7
ILSGA-BP algorithm	45	7

Table 3. Parameters of the proposed ILSGA-BP algorithm.

Parameter	Value
Generation	1100
Crossover	08
Crossover type	Single point
Mutation rate	0.02
Fitness value	0.8

Table 4. The obtained recognition results of facial expressions using radial curves.

Facial Expressions	Disgust	Neutral	Anger	Sadness	Happiness	Fear	Surprise	Accuracy%
Disgust	24	1	2			3		80
Neutral		25	1		2	1	1	83
Anger	1		25	2	2			83
Sadness			2	27		1		90
Happiness					29		1	97
Fear	1		1		1	26	1	87
Surprise						1	29	97
Overall accuracy								88

Table 5. The obtained recognition results of facial expressions using Cubic Bézier curves.

Facial Expressions	Disgust	Neutral	Anger	Sadness	Happiness	Fear	Surprise	Accuracy%
Disgust	25		3			2		83
Neutral		25	2		1	1	1	83
Anger			26	2	1	1		87
Sadness			1	27	1	1		90
Happiness					28	1	1	93
Fear		1			1	27	1	90
Surprise						1	29	97
Overall accuracy								89

Table 6. The obtained recognition results of facial expressions using radial curves and Cubic Bézier curves.

Facial Expressions	Disgust	Neutral	Anger	Sadness	Happiness	Fear	Surprise	Accuracy%
Disgust	28		1			1		93
Neutral		26	1		1	1	1	87
Anger	1		27	1	1			90
Sadness			1	28	1			93
Happiness					29		1	97
Fear					1	29		97
Surprise					1		29	97
Overall accuracy								93.4

Table 7: The overall accuracy results of the traditional BP algorithm and the proposed ILSGA-BP algorithm using extracted features.

Algorithms	Overall accuracy		
	Radial curves	**Cubic Bézier curves**	**Radial curves and Cubic Bézier curves**
Traditional BP algorithm	83%	82%	85%
The proposed ILSGA-BP algorithm	88%	89%	93.4%

3. Experiment based on the combination between the extracted features using radial curves and Cubic Bézier curves.
4. A comparison between the proposed ILSGA-BP algorithm and traditional BP algorithm using the extracted features was illustrated.

Firstly, the obtained facial expression accuracy results based on extracted features using radial curves are disgust 80%, neutral 83%, anger 83%, sadness 90%, happiness 97%, fear 87%, surprise 97%. Table 4 show the Different facial expression accuracy results based on extracted features using radial curves.

Secondly, the obtained facial expression results based on the extracted features using Cubic Bézier curves are disgust 83%, neutral 83%, anger 87%, sadness 90%, happiness 93%, fear 90%, surprise 97%%. Table 5 shows the Different facial expression results based on the extracted features using Cubic Bézier curves.

Thirdly, the obtained facial expression accuracy results based on the combination of the extracted features using radial curves and Cubic Bézier curves are disgust 93%, neutral 87%, anger 90%, sadness 93%, happiness 97%, fear 97%, surprise 97%. Table 6 show the Different facial expression results based on the combination of the extracted features using radial curves and Cubic Bézier curves.

Finally, based on the extracted features using the radial curves, Cubic Bézier curves and the combination of them, the experimental results show that the proposed ILSGA-BP algorithm outperformed the BP algorithm with overall accuracy 88%, 89% and 93.4% respectively, compared to 83%, 82% and 85% respectively using BP algorithm as shown in table 7.

In order to validate the obtained experimental results, the results of the proposed methods were compared with [2]. Where the authors in [2] used the same facial expressions database in [25] as well as the same number of facial images for each expression for testing processes. They obtained a percentage of 78.2% accuracy average compared with accuracy average of 93.4% obtained by the proposed methods in this study. The highest rates were obtained by the proposed ISLGA-BP algorithm, moreover it is obvious that portion of sadness, fear, and anger are misclassified in to happiness, surprise, fear, anger, sadness, disgust respectively with the method in [2], but the proposed ILSGA-BP algorithm classified them with high accuracy rates. The reason behind that is that the FEEDTUM database is difficult to be treated because intra-class confusions (between fear, anger, sadness and disgust on one side and happiness and surprise on the other side) exist, this makes it very difficult to be recognized even by human. In spite of these limitations, our proposed algorithm has a good performance.

5. Discussion

The results obtained from the experiments based on the extracted features using the proposed methods show the success of the ILSGA-BP algorithm in classifying the facial images with different expressions and with various accuracy percentage, for example; the ILSGA-BP algorithm classified the disgust expression with the lowest accuracy and surprise expression with the highest accuracy, the low recognition of the disgust expression is due to that every person expresses the disgust feeling in a different way from others or that different people may feel different emotion toward the same scene. Another examples, in the experiment based on the extracted features using the combination of the radial curves and the Cubic Bézier curves, out of 30 facial images with neutral expressions, 26 were recognized successfully and the remaining were recognized as anger, happiness, fear and surprise. This may attributed to variety of the reactions intensity. Based on the experimental results, it can be concluded that misclassification of the facial recognition with different expressions is related to the emotions. Which significantly attributed to the same or similar output, such as sadness, neutral, happiness and anger, etc[10].

6. Conclusion

This study introduces a novel and automatic approach to recognize human facial expression and emotions using ILSGA-BP algorithm. BP algorithm was used to train and test the extracted feature from the extracted right eye, left eye and mouth using radial curves and Cubic Bézier curves. The comparison shows the superiority of the combination of the radial curves and the Cubic Bézier curves with percentage ranges between 87% and 97% over the radial curves alone with percentage ranges between 80% and 97% and over the Cubic Bézier curves with percentage ranges between 83% and 97%. Moreover, the experimental results show that the proposed ILSGA-BP algorithm outperformed the BP algorithm with overall accuracy 88%, 89% and 93.4% respectively, compared to 83%, 82% and 85% respectively using BP algorithm. In the future, we hope to improve the facial recognition accuracy under expressions, occlusions and pose variation using statistical shape analysis of facial surfaces.

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