Face and Emotion Recognition using Artificial Neural Networks

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***Abstract*—Face and emotion identification using artificial technologies is a promising field with many advantages. This is an active ongoing research area with many successful approaches. Facial Expression recognition has many important applications in digital monitoring, intelligent robots, security applications and major research areas in image processing. Artificial Neural Network focused approaches reached the higher detection rates, accuracy and efficient methodologies. This paper includes a comparative and fundamental analysis about face recognition and emotion recognition using artificial neural networks.**

I. INTRODUCTION

Identify the presence of a face and recognition of emotions based on facial expressions is a simple task for a human being. As a result of successful researches done by past 15 years there are approaches that can detect face and emotions at a high success rate. Darwin [1] has introduced this area as an important research field. After that many methods and algorithms were proposed and developed with time. Face and emotion recognition can be done in three phases. At first face detection should be done. Features extraction from the faces should be done at second. Finally Emotion classification. These stages are separately researched by around the world.

At face detection stage there are many techniques to isolate face from it is background, buildings, accessories, other bodies and various non-face items. According to [2] major face identifying approaches can be given as Branch and bound manner, Exhaustive search manner, and Viola-Jones manner. These methods are optimal but complexity is higher. Artificial Neural Network (ANN) based approach has an increased speed and accuracy. Al-Allaf have noted that "It is important to choose a suitable face classification technique that can provide a good separate ability between different person" [3, p. 2]. These models can work in the way neurons work in the human brain. Based on training data we give, artificial neurons train and learn the network by it is own using various modeling techniques.

Emotion classification stage identify basic emotions. As seen in [4] face acquisition, data extraction from face and demonstration, emotion and expression identification are the three paces comprises in emotion classification. This is also an individually researched area. Context method, Gabor method, Principal Component Analysis, Fishers linear discriminate and Artificial Neural Networks are the manners summarized by Chavan et al. [2]. As by the recognition rate ANN has the highest success rate according to many researches. ANN has different layers to classify expressions. As seen in [5] back propagation manner is mainly used for identification of facial expressions.

This paper will describe a summery review of approaches based on artificial neural networks related to researches on face and emotion recognition. Face recognition and emotion recognition are researched individually by many researchers. This paper includes fundamental techniques about both regions based on artificial neural networks.

II. METHODOLOGY

A. *Face Recognition Algorithms based on neural networks*

Neural Network is consist of input layer, output layer and many number of hidden layers. According to [6] until network reaches the expected goal number of hidden layers and number of units in each layer are chosen by a method based on trials and errors. In other approaches face identification has focused on identifying individual features such as the nose, mouth, eyes, ears and head outline. And based on their positions, relationships and sizes [7]. These approaches are difficult to lengthen to multiple views and not very accurate. ANN is a better technique with avoiding many difficulties. Both non-linear and linear datasets can be used. Neural networks used to identify not only established data but also for unestablished data. In this model there are various approaches proposed to face recognition.

1) Retinal Connected Neural Network: In this method small part of an image is taken and then decide whether each part contains a face [3]. Training and testing is done by using three set of images. System employs multiple layers. Main restriction of this method is it only success at images with front faces. For different head orientations training separate networks and combining together can achieve higher success rate. Success rate of this method was good while there were acceptable amount of false detections as well.

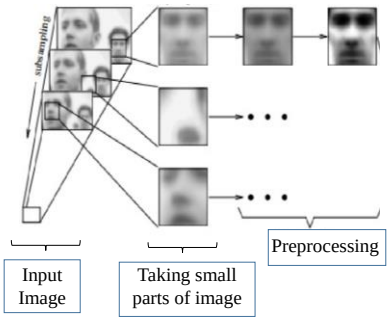

Fig. 1. Considering small windows of an image [3].

2) Rotation Invariant Neural Network: This method can identify faces in images at any degree of rotation within image plane. Within this neural network there are multiple networks to recognize each phases. In first network it identifies the orientation of the images. Then it goes through one or more detector layers then identify the faces [3]. To identify faces throughout the image this approach applies filter at every position in image. When images larger than frame size to reduce it is size images subsampled and applied filters repeatedly. To increase success rate some rotation invariant neural networks has done sensitivity analysis and added more filters.

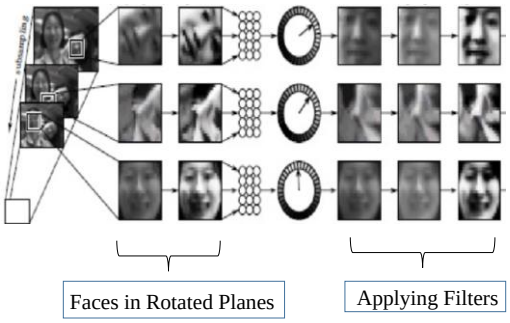

Fig. 2. Faces in rotated image plane [3].

3) Principal Component Analysis with Artificial Neural Networks: In this technique coding method and decoding method used. Saudagare et al. [8] stated that extracted data is first encoded and then compared with the database. After removing noise, image set is divide into two groups as training and testing data sets. By principal component analysis algorithm eigenvalues are calculated and matched with the training data set. Finally feed-forward back propagation neural network is used to identify faces.

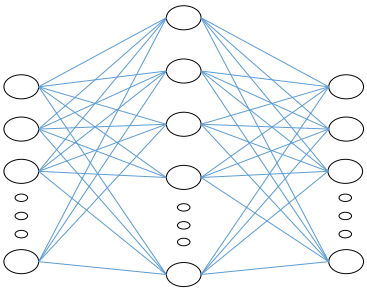

Fig. 3. Example for a feed-forward back propagation neural network [8].

4) Fast Neural Networks: This method is proposed to reduce the calculation time to locate faces. From each image small sub-windows are considered and checked for face recognition using fast neural networks using a parallel processing technology. Divide and conquer principle is used when breaking images into sub-windows. Main limitation of fast neural network is it only recognize frontal faces. According to Kasar et al. [9] to increase the speed of the implementation time a simple procedure is used based on cross corelation between sub windows and weights of the neural network in frequency domain.

5) Convolutional Neural Networks: This model has multilayers which inputs and outputs taken as array vectors. In this architecture convolutional filtering, sampling and classification is done via different layers [10]. This is an advanced model which avoided problems in rotation, translation and scale invariance. To improve the efficiency and reduce the number of non-face images at final layers some convolutional neural network approaches has introduced calibration stages for each detection layers in the network.

6) Gabor Wavelet Faces with Artificial Neural Networks: In this approach gabor wavelet method can be used with feed-forward neural network and back propagation neural network. When using gabor filter position of feature points in input feature vector carries data about faces. False negative and false positive are important data in this study [3].

$$\text{False Negative} = \frac{\text{Number of Missed Faces}}{\text{Total Number of Actual Faces}} \quad (1)$$

$$\text{False Positive} = \frac{\text{Number of Incorrect Detected Faces}}{\text{Total Number of Actual Faces}} \quad (2)$$

Extended neural network with feature space classification technologies improves the successive rate of gabor wavelet faces. Also increasing number of correct faces in training dataset and applying more filters lead to a good performance.

7) Skin color and back propagation neural network: This system contains skin color filter, image filter and detection. According to [3] linear threshold function is proposed for the output. In this model spreading of skin color use to identify regions of skin to predict potential areas of faces. This approach reached a higher success rate and suitable number of false negatives and false positives. System can be executed using C#.

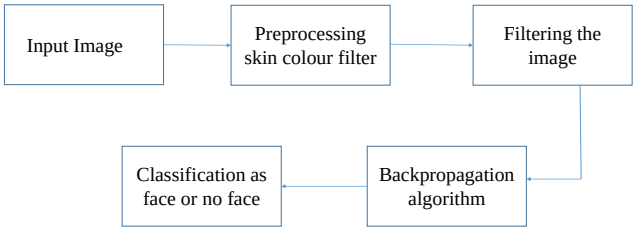

Fig. 4. Example for a skin color and back propagation neural network approach [3].

8) Cascaded Neural Network: This approach reaches greater detection accuracy and efficiency. Al-Allaf have states that "organized neural network ensembles in a pruning cascade to reduce the total computation cost of face detection" [3, p. 11]. To perform a neural network ensemble many number of classifiers used. These ensembles identifies faces from it is background more efficiently and lead to a higher success rate.

9) *Multilayer Perceptron:* This is an efficient approach that consist of pre stage neural network which can identify and reject most of non-face images. This manner is based on multi-layer perceptron and maximal rejection classifier. This approach gives best results for efficiency, computation time, false positives and detection rate.

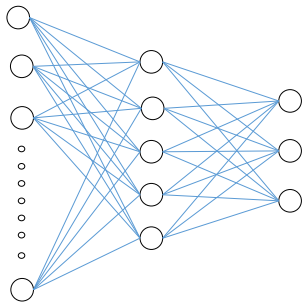

Fig. 5. Example for a Multilayer Perceptron Neural Network [11]

10) Polynomial Neural Network: this approach is a deviation of principal component analysis algorithm. At early layers face and non-face images were separated using polynomial neural network.

B. *Facial Feature Extraction and Expression Recognition Methods based on neural networks*

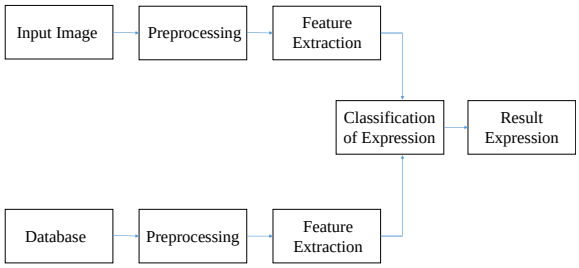

Fig. 6. Facial expression identification steps [12]

Seven fundamental emotions can be identified using these methods. As described in [13] basic emotions are fear, angry, surprise, happy, disgust, sad and neutral. These emotions can be expressed in individually or combinations with other emotions. According to [12] elderly has a negative impact on facial expression recognition accuracy. Wrinkles and lessened elasticity of muscles deviate some expressions performed by older people. Problems associated with aging can be reduced by using a weighted least square filter [12].

$$\sum\left((b_p - l_p)^2 + C\left(a_{x,p}(l)\left(\frac{\partial b}{\partial x}\right)_p^2 + a_{y,p}(l)\left(\frac{\partial b}{\partial y}\right)_p^2\right)\right) \quad (3)$$

Where l = Gray level of face image
b = base layer
a_x = smoothness weights along x direction
a_y = smoothness weights along y direction
p = spatial location of a pixel
c = balance terms

Smoothness weights can be calculated as follow

$$a_{x,p}(l) = \left(\left(\frac{\partial l}{\partial x}(p)\right)^{\alpha} + \varepsilon\right)^{-1} \quad (4)$$

$$a_{y,p}(l) = \left(\left(\frac{\partial l}{\partial y}(p)\right)^{\alpha} + \varepsilon\right)^{-1} \quad (5)$$

1) Luminance, Chrominance, Geometry and Symmetry based Approach: Regardless of the differences in size, shape and structure of the faces symmetry is very helpful in detecting features. As shown in [14] in normal lightning conditions features as nose, mouth and eyes include low gray levels relatively. Using an intensity histogram light and dark regions of the face can be classified. According to that eyes, cheeks and forehead are the main parts that can be identified in a face using this method. Various algorithms were proposed using this approach of feature extraction.

2) Template Based Approach: In this method separate template is used to identify each feature. Eyes, nose and outline of the face is mainly consider here. When feature extraction from eye this method also used template individually for iris, eye corner and eyelid. To get a better accuracy and efficiency this method is focused on uniqueness of features.

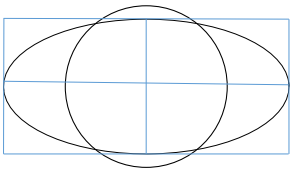

Fig. 7. Example for an extraction of eye using a template [14]

3) Principal Component Analysis based Approach: Entire face consideration and illumination deviations tend to happen distortions in Principal Component Analysis (PCA). Localized PCA based approach have proposed to

escape those difficulties. In preprocessing stage most of the noise is removed. Eigen values detected from PCA algorithm used to identify best Eigen faces. Using this principal component analysis based approach facial expression recognition can be done efficiently.

4) Back Propagation Method: This is the most accurate and widely used method for facial feature extraction. According to [8] different procedures are proposed to extract features such as mouth, cheeks, forehead and mid forehead. As stated in [15] four phases of back propagation network can be identified.

- Weights loading
- Feed forward methodology
- Back propagate errors
- Weights updating

Variation of number of layers and nodes, weight techniques, learning rate and error values can lead to better achievements in back propagation neural network approach.

5) Convolutional Neural Network Architecture: As seen in [16] when the image is received as an input for convolutional neural network it passes through multiple layers. After learning process identifying features it outputs a vector with seven emotions. To improve accuracy some approaches use temporal features. According to [17] Deep Temporal Appearance Geometry Network is introduced to extract appearance qualities and geometrical qualities from temporal features. Deep neural network and a Gabor filter is used to get an enhanced accuracy. There were many approaches based on convolutional neural network as follows.

- Attention mechanism based
- Local facial patch based
- Patch based
- Global local based
- Local patches with global images

6) *Other Neural Network Approaches*: As seen in [6] neural networks take input images as gray scale images. Three types of emotions are organized as astonished, calm and smiling. In this approach mainly focused on mouth information. To get a higher detection rate modified back propagation training method is proposed. Examples for other neural network approaches can be shown as follows.

- Multilayer perceptron based
- Radial basis function networks
- Signaled emotions and the level of expressiveness
- Ensemble based
- Neuro-fuzzy network

III. RESULTS

Dataset is the major component that determines the success of face and emotion recognition using artificial neural network approaches. 2D datasets are most commonly used for recognize facial behaviors. For further recognition of micro features 3D datasets are also used. It is necessary to identify suitable data set for each approach. Followings are the most commonly used datasets for different methods [17].

- Japanese Female Face Expression dataset (JAFFE)
- Extended CohnKanade Dataset (CK+)
- MMI Facial Expression based Dataset
- NVIE Dataset

According to training, testing datasets, number of iterations for training and different kind of data sets can vary results of the neural network.

TABLE I. APPROXIMATE PERFORMANCE OF DIFFERENT TECHNOLOGIES

Research	**Neural Network Approach**		
	Topology	***Performance***	***Accuracy***
[3]	Retinal Connected Neural Network	Acceptable	78%-91%
[18]	Rotation Invarient Neural Network	Up right data	80%-90%
		Rotated data	85%-92%
[8]	Principal Component Analysis	1.2% Error	90.5%
[9]	Fast Neural Networks	High speed achieved	85%-95%
[3]	Convolutional Neural Network	Set of 5600 images	97.6%
[3]	Gabor Wavelet Method with ANN	Set of 130 images	77%-91%
[19]	Skin color and back propagation neural network	Has acceptable amount of accuracy	76%
[11]	Multilayer Perceptron	7.54% Error	91.6%

Research	Neural Network Approach		
	Topology	*Performance*	*Accuracy*
[14]	Template based approach	Errors due to strong illumination	88%-94%
[15]	Back Propagation Neural Network	Processing time varies by image size and number of iteration	86%-97.3%
[3]	Polynomial Neural Network	False rate 3:51	84.6%

IV. CONCLUSION

This paper summarize basic information about main approaches related to face and emotion recognition technologies based on artificial neural networks during past few decades. Face detection algorithms were identified at first section. Feature extraction technologies and emotion recognition methodologies were introduced then. As conclusion comparative analysis is performed in result section.

By studying many approaches it seems controlling system parameters such as learning rate, error rate and training data sets leads to differences in accuracy. There were many researches with higher accuracy, performance and less computational time.

For future work this is a heavily researched area and there are many ongoing researches about face and emotion recognition. Each approaches has its own limitations and strengths. Several of other neural network approaches and structures mentioned here can be used to get best performance with higher success rate.

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