



# Face Recognition Technology Based on Neural Network: A Review

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## Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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## ABSTRACT

An artificial neural network (ANN) is an information processing system established by simulating the structure and logical thinking of the human brain. It uses the interconnection between a large number of neurons to form a network system that can perform complex calculations, and is widely used. For various complex problems, by choosing different model structures and transfer functions, various neural networks can be formed and different expressions of the relationship between output and input can be obtained. Face recognition is one of the important research directions of ANN. It mainly refers to the automatic inference of identity, expression, age, gender and other attribute information through the analysis of facial images, videos or pictures and video collections of people. Widely used in mobile payment, safe city, criminal investigation and other fields. The origin, types and research progress of ANN are introduced, and the face recognition technology based on neural network are investigated.

**Keywords:** Artificial neural network; logical algorithm; neural network; RBF neural network; convolutional neural networks.

## 1. INTRODUCTION

With the advent of computer technology, people have discovered that its computing power far

exceeds that of humans. However, computers often cannot be used as effective auxiliary tools for problems involving judgment, classification, and not clearly defined, such as data prediction,

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image classification and so on. In the summer of 1956, the Artificial Intelligence Symposium was held at Dartmouth College, where McCarthy first proposed the concept of "artificial intelligence (AI, artificial intelligence)". AI is the research and development of new technologies for simulating, extending and expanding human intelligence theories, methods, technologies and application systems. As a branch of AI, artificial neural network (ANN) processes some irregular functional relationships by simulating the thinking logic of the human brain, so as to solve some complex p

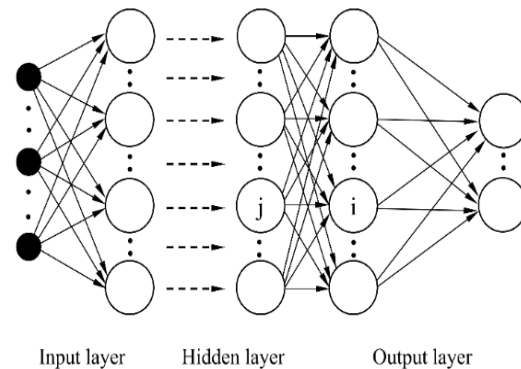
ANN is a logical algorithm for information processing by simulating the way of thinking of the human brain. Every connection in the network is similar to the synapse between neurons, which can transmit information. The interconnection between neurons forms a neural network to obtain the final feedback [1,2]. The unique structure and information processing method of neural network make it have obvious advantages in many aspects and have a wide range of applications. The main application fields include intelligent driving [3-5], robot control [6], automatic power system control [7], signal processing [8,9], chemical process control and optimization [10-12], image processing [13,14], health care and medical treatment [15,16] and game theory [17]. This article will mainly introduce the origin and types of neural network, and analyze its application research progress in the field of face recognition.

## 2. THE ORIGIN OF ARTIFICIAL NEURAL NETWORK

### 2.1 The Structure of ANN

Fig. 1 is a schematic diagram of the structure of ANN. From Fig. 1, it can be seen that an artificial neural network consists of an input layer, a hidden layer and an output layer. There are several nodes (neurons) and every node represents a specific output function (called the activation function). Each connection between two nodes represents a weighted value for the signal passing through that connection. By substituting the output, weight, and bias of the neurons in this layer into the activation function, the input of the neurons in the next layer can be obtained, and finally the output value can be obtained [18,19]. The working principle of ANN is: firstly, the input layer receives external information and data, then the hidden layer continuously adjusts the connection properties between neurons for information processing, and

finally the output layer gives the results. The weight reflects the connection strength between the units, and the feedback represents the positive and negative correlation between the units.



**Fig. 1. The structure of artificial neural network**

### 2.2 Research Progress of ANN

In 1943, McCulloch and Pitts [20] proposed a research method for mathematical simulation by simulating biological nerve cells, called the M-P model, which marked the birth of artificial neural networks. Then, the Hebb learning rule proposed by Hebb [21] is still a basic principle of neural network learning algorithms; in 1960, Widrow [22] proposed an adaptive (Adaline) linear element model. These models and algorithms enrich the neural network system theory to a great extent. But the development of neural networks stagnated for nearly 20 years due to difficulties encountered with the crossing limits of electronic circuits. Around the 1980s, a number of scientists successively proposed a variety of new theories and methods, the most representative of which are: ART network, cognitive machine network, Boltzmann machine, parallel distributed processing, etc., which addresses the two problems raised by Minsky [23]. Marked by the Hopfield model proposed by Hopfield [24], ANNs have entered a new era of development. Rumelhart et al. [25] proposed a multilayer feedforward network (BP) algorithm. The characteristic of the BP algorithm is that it uses a bidirectional feedback mechanism, which can minimize the instantaneous error signal. At the turn of the 21st century, the work of two scientists made ANN technology really move towards a practical stage, they are the support vector machine SVM algorithm proposed by Vapnik [26] and the pre-training method of Hinton [27].

Since the advent of the Hopfield network model [24], artificial neural network technology has developed many models, which simulate the basic laws of physics, chemistry, biology, medicine and other industries, and realize the sorting and transmission of information. The following will introduce the three most used neural networks: Feedforward Neural Network (BPNN), Radial Basis Neural Network (RBFNN) and Convolutional Neural Network (CNN).

### 2.3 Feedback Neural Network (BPNN)

Rumelhart et al. [25] proposed BPNN to compensate for the shortcomings of multi-layer neural networks. The basic method of BPNN is to first provide the experimental data to the neural network as the learning samples for training, and then modify the weight based on the error between the output value and the expected ones until the error between them meets the accuracy requirements. The detailed method is described as following [28,29]:

(1) Take the sum ( $J_d$ ) of squared errors of neurons in the output layer as the objective function in Equation 1 to find the weight and bias when it is minimal:

$$J_d = \sum_{i \in \text{output layer}} (t_i - y_i)^2 \quad (1)$$

where  $t_i$  and  $y_i$  are the predicted and actual values, respectively.

(2) Using the stochastic gradient descent algorithm, the error is optimized as shown in equation (2):

$$\omega_{j,i+1} = \omega_{ji} - \eta \frac{\partial J_d}{\partial \omega_{ji}} \quad (2)$$

where the partial derivative is calculated by the chain derivation rule, and is treated based on the site of the  $j$  node.

The error terms of the output layer, hidden layer and input layer are calculated in turn, and all weights are updated [30]. The weights are adjusted all the time. After multiple rounds of iterations, the weights of the network model can be trained to ensure that the objective function is achieved.

### 2.4 RBF Neural Network

The output value of RBFNN is not a specific number, but a set of smooth numbers. Since it transmits information by radial basis function and has only one hidden layer, RBFNN is better than BPNN in function approximation, classification ability and learning speed [31].

### 2.5 Convolutional Neural Networks (CNN)

Vaillant et al. [32] applied convolutional neural networks to face detection as early as 1998, but it was not until 2012 that the convolutional neural network AlexNet [33] made a major breakthrough in image recognition. The most important contribution of LeCun [34] is to use LeNet-5 with deep structure as a classifier for image recognition. Specifically, it includes input layer, convolution layer, pooling layer, fully connected layer and output layer. CNN reduces the number of parameters that the neural network needs to train through local receptive field and weight sharing. The difference between the CNN and the ordinary neural network is that it contains a feature extractor composed of a convolutional layer and a subsampling layer. In a convolutional layer of a convolutional neural network, a neuron is only connected to some of its neighbors. Krizhevsky et al. [35] proposed AlexNet, which greatly improved the classification accuracy on the Image Net dataset.

## 3. RESEARCH OF FACE RECOGNITION TECHNOLOGY BASED ON ANN

In the past decade, with the increasing requirements of intelligent manufacturing and intelligent driving technology, a lot of work has been done to improve the accuracy of object detection and recognition. Traditional face recognition algorithms such as Principal Component Analysis (PCA) have certain shortcomings in terms of accuracy and characteristics. Face recognition with the help of artificial neural networks has become mainstream. In general, face recognition can rely on local information (e.g. eyebrows, cheeks, chin) and non-component/holistic information (spatial relationships between them), although they are not yet optimally integrated.

Belhumeur, Swets and Barlett et al. [36-38] proposed the Fisherman Face method (FLD) to leverage class information to enhance the discriminative ability. These algorithms are largely based on maximizing the ratio between

the "class scatter matrix" to the "within class scatter matrix" to find another subspace that best distinguishes the input data, where LDA is applied to the classification of PCA-transformed face data, that is, "PCA+LDA". In the face recognition process, PCA or LDA is used to extract the face features and is classified by ANN using radial basis function (RBF) network [39,40] or backpropagation (BP) [41-43]. When a back-propagated neural network was used to classify 40 face subjects using facial features provided by PCA and LDA, the face recognition results were shown to be superior to Euclidean distance [44].

Rama Linga Reddy et al. [45] proposed a new algorithm using multi-scale face components and Eigen/Fisher features of artificial neural networks. The basic idea of this method is to downsample the face components of different resolutions such as eyes, nose, mouth and full face according to the saliency of the face components, and perform subspace principal component analysis (PCA) or linear analysis to construct face feature vector. They studied the face recognition performance of PCA+BP, PCA+RBF, LDA+BP and LDA+RBF for the multi-scale features of the ORL face database. 200 Faces of 40 subjects were used for training, and another 200 faces are used for testing. The results showed that the LDA+RBF method achieves a recognition rate of 98.40% for 40 objects with an image size of 112×92 with a 40:50:40 ANN structure.

Deotale et al. [46] proposed an unsupervised neural network that can be applied to face recognition which is especially suitable for passport and police registration. The system combines local image sampling and self-organizing map neural network. The images of different people scanned first are used as a database for network training and learning. Scanned images will be resized according to the SOM schema.

Chen et al. [47] proposed the concept of face candidate regions, and used the Adboost face detector to prejudge all candidate regions and reserve the candidate regions. Then, a small-scale CNN was used to judge whether the candidate area is a face, and a medium-scale CNN was used to complete the classification of all candidate areas.

Gao et al. [48] proposed an image matching method with rotation and scale invariance. The model first established sparse keypoint matching

based on local invariant features, and then used the sparse matching result as a reference to complete dense matching. Finally, the dense matching relationship of the wide baseline image is obtained. According to the matching correspondence, the depth information in the two-dimensional image can be recovered, and the three-dimensional reconstruction of the target scene can be realized. Shi et al. [49] made the method affine-invariant by extracting affine-invariant features in the image, which improved the robustness of the model.

Existing face recognition algorithms are vulnerable to various face presentation attacks (face-PA), such as printing paper, video playback, and silicone masks. To deal with the above problems optimally, Zhao et al. [50] constructed a novel deep neural network to deeply encode facial regions and utilized PCA to reduce the dimensionality of deep features while removing redundant and polluted visual feature. A joint Bayesian framework is then used to evaluate the similarity of feature vectors, and finally a face recognition performance of 98.52% was achieved. Zangeneh et al. [51] proposed a novel coupled mapping method for low-resolution face recognition using deep convolutional neural networks (DCNNs). Its architecture consists of two branches of DCNN that map high- and low-resolution face images into a common space with nonlinear transformations. The distances between the features of the corresponding high-resolution and low-resolution images are back-propagated to train the network. The method is evaluated on the FERET, LFW, and MBGC datasets and compared to state-of-the-art competing methods, achieving a 5% improvement in recognition accuracy. Moghadam et al. [52] proposed a novel dynamic deep bottleneck neural network for analyzing and extracting three main features of videos about facial expressions. The proposed model has the advantages of recurrent networks and can be used to analyze the sequence and dynamics of information in videos. The model achieved an average accuracy of 97.77% in identifying the six salient emotions (fear, surprise, sadness, anger, disgust, and happiness) and 78.17% accuracy in identifying emotions. Soni et al. [53] proposed a simple and effective face recognition system using deep learning concepts. It consists of four main steps: preprocessing, cascade feature extraction, optimal feature selection, and identification. The preprocessing of face images mainly focuses on the face detection of the Viola-Jones algorithm. Local Diagonal Extremal

Number Pattern (LDENP) is applied to cascade feature extraction. A hybrid meta-heuristic concept, Multi-Verse with Colliding Bodies Optimization (MV-CBO), is used to perform optimal feature selection. Face recognition is performed by an optimized deep neural network (DNN) based on the optimally selected features. Extensive experiments on several benchmark databases demonstrate that the proposed model outperforms existing face recognition methods. Yu et al. [54] constructed a face recognition system based on neural computing models and neural network principles. The experimental results showed that the detection rate of the method is higher and the processing time is shorter.

#### 4. CONCLUSION

As a paradigm for solving fuzzy problems in the era of intelligence, artificial neural networks have provided many application examples for the era of intelligence. In the future, with the development of hardware technology, the fragmentation and marginalization of cloud services, the intelligence and informatization of cities, and the application of artificial neural networks will increase. Facial recognition is becoming increasingly important in developing a secure environment for organizations and also enhances the use of artificial intelligence in security. For many years, people have been studying face recognition to accurately identify complete face images. Although a lot of research has been done on handling occluded and noisy images, more refinement is still required to achieve high accuracy.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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