A Review on Facial Expression Recognition System using Deep Learning

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Abstract*— Human emotions are spontaneous and conscious mental states of feeling that are accompanied by physiological changes in the face muscles implying face expression. Some important emotions are happy, sad, anger, disgust, fear, surprise, neutral, etc. In non-verbal communication, facial expressions play a very important role because of the inner feelings of a person that reflect on faces. A lot of studies have been carried out for the computer modeling of human emotion. However, it's far behind the human vision system. In the area of computer vision, academic research in deep learning, specifically research into convolutional neural networks, received a lot of attention with the fast growth of computer hardware & the arrival of the Big Data era. Many researches & studies on emotion recognition & deep learning methods are carried out to identify emotions. This article presents a survey of Face Expression Recognition (FER) methods, including 3 key phases as pre-processing, extraction of features & classification. This survey discusses the many kinds of FER methods followed by categories & methods of emotional recognition. It also gives a brief overview of the deep learning approaches used in the FER classification system for facial emotion.

Keywords*— Detecting emotion, Emotion Recognition, Facial emotions. Facial Expression, Facial emotional recognition, Deep learning.

I. INTRODUCTION

Emotion plays a significant role in interpersonal communication and they represent a psychological state of the human mind and thought processes. Facial expressions and movements provide nonverbal knowledge that contributes to human communication. Expression recognition involves a series of facial characteristics to be extracted from a given subject's facial expression. Recognition of emotion involves classifying facial characteristics into one of many categories of emotion. The function of identifying the emotion, therefore, is a question of pattern recognition despite the expression of an emotion. The main objective of this research is to use facial recognition methods to detect emotions on faces. Several applications in the area of human-computer interaction can be supported by identifying facial expressions from facial images. For example, facial recognition can assist health providers to detect pain or assist with mental health analyses. It combines both face detection measurement & expression recognition. Facial recognition is the initial stage of the recognition system for facial expression in images in input frames. Different facial feature extraction methods may be used for finding face position [1].

The identification of facial expression is an area of advancement, including domains like neuromarketing. Facial expressions are significant factors that help us to understand the intentions of others in human communication. In several types of variations, even images of the same person may differ. Even though it has been researched much earlier, few studies which illustrated fair work were avoided when training & testing. Facial emotion is a major important feature of human emotion recognition. Face detection enables the identification & validation of human faces from images, videos & other forms of graphics. It traces face features, contours & structure to analyze individuals' unique biometric & demographic details. A face is always human's most sensitive & communicative part. Anger, disgust, fear, happiness, neutral, sad & surprise is all facial expressions. A smile on the human face displays its happiness & expresses the eye in a curved form [2].

Figure 1. Types of Facial Expression

(Source: https://managementmania.com/en/six-basic-emotions)

Humans hierarchically order their thoughts and principles. People will learn basic concepts first and write them to represent more complex concepts. The human mind is like a DNN, composed of several neuron layers serving as role detectors, which sense more abstract characteristics as their levels increase. This is simpler for computers to generalize knowledge in a more complex manner. The key value of DL is its condensed representation of a broader variety of functions than low networks used by the more common form of learning [3].

Facial expressions provide valuable detail about a person's emotions. Face recognition is an evolving area, changing and improving constantly. Feature extraction approaches may be classified by focusing on motion or deformation of face & facial features or acting locally or holistically respectively. Extraction of face features is to discover the most appropriate representation of face image recognition. Recognition of facial expression has many possible uses that have been attracted by researchers in the last decade. Today deep learning is an area of machine learning that is both present and motivating. Deep learning is the most efficient, tracked, time-consuming, & economical form of machine learning. Deep learning in many areas included the widespread areas of deep learning, cancer identification, natural language processing, object detection, stock market research, computer vision, facial recognition, speech recognition, smart city, and many others has made significant improvements or efficiency in many fields of use. This article uses deep learning

approaches for the recognition of facial expressions rather than handmade features. A deep learning algorithm is a breakthrough in recognition tasks recently, as most identification tasks world records have been broken two types of deep networks like deep-neural network (DNN) & convolutional neural networks (CNN) are generally used to resolve issues with recognition. Feature extraction & categorization were recognized in the architecture of Convolution Neural Networks (CNN) [4, 5].

The rest of paper is systematized as follows: section II elaborates review on emotion recognition with their categories & techniques used in ER. Section III gives a small introduction of Facial Expression Recognition system. It talks about various deep learning techniques in Section IV. Section V present the literature work in FER using different deep learning techniques. At last, Section VI concludes this work.

II. EMOTION RECOGNITION

Emotion is a fundamental component of being human. In human daily social life, knowing the emotional feeling of the counterpart is intuitive, but, when it comes to the computer, this is much harder. Emotion could be expressed through unimodal social behaviors, including speech, facial expressions, text, gesture, etc., or bimodal such as speech and facial, brain signals and facial, speech and text, etc., or it could be expressed through multimodal such as audio, video, physiological signals and so on.

Emotion detection is a major concern in the kind of section of affective computing, which is considered with the analysis & creation of systems & devices which could perceive, interpret, & simulate human feelings. The knowledge of emotion is referred to as affect. If Professor Picard first introduced affective computing in 1995, he described it as "that computing which connects to, emerges from, & actively influences feelings." It uses artificial intelligence to impart information to the system it produces. Facial features and efficiency of speaking made, physiological signals of a human body, & articulated gestures all are instances of data that can be used to classify feelings. Happy, surprise, disgust, sad, anger, and fear facial expressions Emotion are of facial recognition. Let's take a closer look at these classification data [6, 7]

Table 1: The table below provides key emotions FE

Emotion	Facial Expression
Anger	Look in the mind, Dilated nostrils, Lips were strongly pressed
Happiness	Raised cheeks, widened side of lips
Surprise	Strong eyebrows curved, A more visible eye
Disgust	Lips Raised, Wrinkle's nose
Sadness	Skin triangulated under the eyebrow; Upper eyelid pulled in.
Fear	Growing eyebrows, Open the mouth

A. Categories of Emotions Recognition

1. Facial Expressions

Detecting feelings through facial expressions is one of the simplest & oldest strategies. It has a long history since it is thought to relate to key aspects of sentiments. As a result, various methods for categorizing feelings based on facial expressions have been established. All of these methods are founded on the notion which feelings signals could be deduced from the spatial configuration of specific things & regions on a face [8].

2. Speech

In a speech, that speaker's sound not only conveys a semantic msg but as well data about his or her touching state. There are several attributes of speech that can be used to identify it. The vibration of vocal cords is a major source of power in expression. The fundamental frequency of an acoustic signal is the speed at that cords pulsate. It alludes to a voice's tone. The prosody is made up of differences in pitch & strength together. Pitch, strength, and interval of speech, & spectral properties are the acoustic features of voice [9].

3. Physiological Signals

The physiological signal is not directly relevant to feeling, but the knowledge from signals may be used to aim or recognize emotions. Depending on a point of origin, it may be divided into 2 categories. [10] The first group of signals comes from the peripheral nervous system, like heart rate ECG & EMG skin conductance & the second category comes from the central nervous system, like brain signals (EEG).

4. Multimodal Information

Multimodal Information for identifying emotions you could use a variation of any of the techniques listed above. If more than one kind of data is used for emotion detection, data is said to be multimodal, & data or information employed for the aim of feeling detection. Combining facial expressions & speech signals, for instance, generates an audiovisual signal, which is the latest type of data [11].

B. Techniques used for Emotion Recognition

1. Principal Component Analysis

Principal Constituents Analysis (PCA) [12] is a tool for analyzing patterns in data & describing them in a way that emphasizes their separation & commonality. PCA is used to remove features by Input images to identify facial expressions utilizing eigenfaces. To start, they create a working dataset with which to compare the performance. If the face image has been pre-processed, it is matched to a training dataset, which was already calculated, but they divided a training set into 6 simple groups based on universal voice (Happy, Surprise, Disgust, Sad, Angry, Fear).

2. Local Binary Pattern

For its excellent light invariance property & low computational complication, the LBP-based feature extraction process [12] is used. The outcome is viewed as a binary number after the neighborhood value is thresholded by the center value. If an amount of canter pixels is better than any amount of a neighbor, write 1, otherwise 0. In these manners, it effectively encodes knowledge about neighborhoods.

3. Active Appearance Model

The Active Appearance model [12] is the statistic method for shape and texture modeling & feature extraction. It's the preferred choice for computer vision software. By integrating the model of shape dissimilarity with the model of texture variant, AAM develops statistical appearance models. As a product, the AAM generates a training facial image series form & texture grouping model. “Textures” are a target image's pixel intensities.

4. Facial Action Coding System (FACS)

It is a system of measuring facial features which were established through Paul Ekman & Wallace Friesen in 1976. A FACS approach [12] is according to the study of association among muscle contraction & the appearance of a face. Upper & Lower Face Action Modules could be found on the face. Modification in the face caused through a single muscle or a group of muscles is referred to as Action Units. Updates in facial features are described through 46 AUs, & eye contact direction & head orientation are expressed through 12 AUs.

C. Haar Classifier

For its owing high detection accuracy & real-time output, the Haar classifier-based approach [12] is selected for face recognition. The amount of a function is a variation of a no. pixel values in white & black areas, & it is made up of black & white related rectangles. The use of Integral images Improves the computational speed of function measurement.

III. FACE EXPRESSION RECOGNITION

Facial expression recognition plays important role in human beings to express situations & understand the intentions of others. It is an important feature to recognize human emotions. Facial expression is a predicament of feeling like emotions, thoughts, and different modes. The facial expressions are commonly sorted into 6 basic universal expressions such as surprise, sadness, happiness, fear, disgust, and anger also neutral. However, dominant expression recognition remains a challenging act. Face expression recognition has wide miscellaneous applications such as video conferencing, medical, telecommunication, automatic counseling system, music for mood, lie detection and other latest and growing application of facial expression recognition is artificial intelligence in which robots should have the capability to read human expressions and then reply according to necessity. The objective of the face expressions recognition system is built of this special human sapience in a machine. FER architecture is divided into three parts, Face detection is the first part, which detects expression from an image known as preprocessing, second is features extraction and third is a classification that classifies basic expressions.

A. Face Expression Recognition System

Fig. 2 shows an overview of the FER system. A FER system comprises important phases like facial picture preprocessing, extraction & categorization of features.

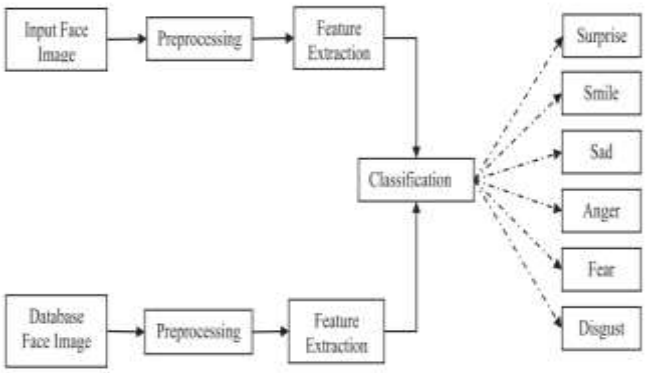

Figure 2. Facial Expression Recognition system

(Source: https://ars.els-cdn.com/content/image/1-s2.0-S1319157818303379-gr1_lrg.jpg)

1. Preprocessing

Preprocessing is an important part to increase the performance quality of the facial expressions recognition system and this phase effectuates before the feature extraction process. The image preprocessing stage comprises apart processes such as improve image clarity, suppress unwanted features, geometric transformation, enhances facial features and expression frames to improve quality.

2. Face Detection

Face Detection is the first and important stage for facial expression recognition. It is the process of detecting and localizing faces in an image. The method of face detection in images is a sophisticated cause of variability present in human faces like gesture, expressions, position, skin color, hairs present on the face, the disparity in camera quality condition, gain, and image resolution

3. Feature Extraction

It is termed feature extraction to extract useful data from image/input signals. Extraction of the Gabor feature, optical flow method, local binary pattern, tracking of the feature point & several approaches used. The geometric & appearance-based can be categorized. Geometric Facial expression recognition systems not only extract form & locations but also angles between different face components, such as eyes, ears, mouth & nose. Its geometrical connection shows feature vectors.

4. Classification

Classification is the final step of the facial expression recognition system; the classifier categorizes face expressions. Its accuracy is based on local neighbors. In this paper, the Support vector machine uses as a classifier and analyzes data used for classification which has 2 kinds of methods. They are one against one and one against all approaches. One against all classification implies it build one example for each category. One against one classification means to build one example for every pair of categories. It utilizes kernels function for its better outcome. Kernel function use for nonlinear data, it takes low dimensional feature space input and gives high dimensional output. Then input data in non-separable form, when data passed through kernel to convert into high dimensional it is separable and can classify [13-15].

IV. DEEP LEARNING

It is an approach for machine learning that model's data to do a specific task. Deep learning in neural networks is widely used to detect pictures, classification, decision making, recognize patterns, etc. Other methods of deep learning such as multimodal deep learning is also used to select features, recognize images, etc. [16]. Deep learning is recently become a popular research topic & has obtained state-of-the-art performance for a range of applications. Deep learning is attempted to capture abstraction at a high level by hierarchical structures with numerous nonlinear transformations & representations. We define certain deep learning approaches that were used to FER briefly in this section. Deep neural networks are conventionally architecture in Fig. 3. Deep learning is often called deep structured learning. It is one of the learning approaches focused on the representation of learning results. Learning may be supervised, semi-supervised & unsupervised. Four models are used in deep learning methods: stacked autoencoder, DBN, CNN, or RNN

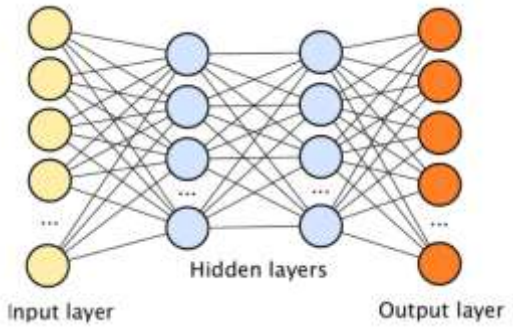

Figure 3. Layers of Deep Learning

(Source: https://stackabuse.com/deep-learning-in-keras-building-a-deep-learning-model)

1. Convolutional neural network (CNN)

In several computer vision applications, like FER, CNN has been extensively used. Various FER literature research around the beginning of the 21st century found that CNN is stronger in the situation of position changes & scale differences than multilayer perceptron (MLP) when the face changes were previously unseen. A CNN was used to solve problems of the subject independence & the recognition of facial expressions in rotation, translation & scale invariance.

2. Deep belief network (DBN)

It is proposed by Hinton as the graphic model that learns to extract the training data from the deep hierarchy. A conventional DBN consists of a stack of Restricted Boltzmann Machines (RBMs) which are generative two-layer stochastic models made of visible unit layer & hidden unit layer. The units in the higher layer are trained for situations of units in adjacent lower layers in DBN except for the top 2 layers that have undirected connections.

3. Deep autoencoder (DAE)

DAE learned effective coding to reduce dimensionality. In contrast to the above networks that forecast target values, DAE is optimized to restructure its input by reducing reconstruction error.

4. Recurrent neural network (RNN)

It is a connectivity model which includes temporal data & is better suited for arbitrary sequence data prediction with arbitrary length. Besides the training of the deep neural network in a single feedback manner, RNNs contain recurrent edge which span adjacent periods, & which share same parameters in all phases. A conventional BPTT (backpropagation through time is utilized to train RNN.

5. Long-short term memory (LSTM)

Hochreiter & Schmidhuber invented LSTM, a unique variant of conventional RNN that addresses vanishing in gradients & explosive difficulties that are frequent in RNN training. An LSTM cell condition is controlled through 3 gates: an input gate that allows cell state alteration or blocks the input signal, an output gate that allows or prevents cell state from affecting other neurons, & a forgotten gate that modulates self-recurrent connection to collect or forget its previous state.

6. Restricted Boltzmann Machines (RBM)

It is a stochastic NN of 2 layers that can be used to reduce dimensionality, classify, teach function and work together. The regular RBM form has binary nodes & bias weights. RBM attempts to learn binary code or input representation, & RBM may be conditioned, either in supervised or unattended ways, depending on a specific mission. RBM is normally used for learning features [17-20].

V. LITERATURE REVIEW

A present paper reviews studies & research finding of recognizing the face expression based on research literature both at home & abroad in recent years, from feature extraction expression, classification & face recognition

K. Tsai et al. (2018) In this article, proposed a FER system based on advanced neural CNN. It utilizes facial frontalization & positioning methods to minimize the influence of background noise & non-prominent components. In addition to hierarchical structure & adaptive exponentially weighted average ensemble, precisions are increased. Simulations on various datasets reveal that the system proposed outperforms state of art FER approaches & may well detect a person's expression [21].

J. -H. Kim (2019) article proposes a novel FER system based on hierarchical deep learning. Proposed algorithm for CK+ & JAFFE datasets that are usually considered confirmed data sets for recognition of facial expression. A finding of 10-fold cross-validation demonstrates 96.46% of the preciseness in the CK+ data set and 91.27% of the precision in the JAFFE data set. In comparison with existing approaches, up to 3% of accuracy increase & 1.3% of the average CK+ data set enhancement is shown in the proposed hierarchical deep network structure. Up to 7% of accuracy in JAFFE data sets is improved & the average increase is confirmed by around 1.5%. [22].

S. Lin et al. (2019) propose in this study a continuous model for facial expression recognition based on a deep learning technique that combines CNN & RNN to analyze & detect continuous face expressions over some time to enhance conventional image recognition technique [23].

P. Kaviya and T. Arumugaprakash (2020) In this article, a deep learning technique is proposed for a human face sentiment identification system. A Haar filter is used to detect & extract facial features in this framework. A CNN then develops to recognize & classify facial expressions into 5 fundamental emotional states: happy, sad, anger, surprise & neutral. Group emotions predicted are finally fed in an audio synthesizer to receive audio output. For FER-2013 & 60% for custom data sets, the proposed model obtains a final accuracy of 65% [24].

P. Babajee et al. (2020) analyze the identification of human facial expressions by deep learning method using CNN algorithm. For training & testing, the system uses labeled data set of approximately 32,298 pictures with various facial expressions. A pre-training step includes a noise reduction facial detection subsystem containing feature extraction. The outcomes of their work show an accuracy of 79.8% to identify all 7 fundamental human emotions without using optimization methods [25].

L. Cai et al. (2020) This article proposes a strategy combining the features of speech & facial expression. They learn speech emotional features via CNN & LSTM. The simultaneous extraction of face expression features through various small-scale kernel convolution blocks. Finally, DNNs were used to fuse face & speech expression features. An IEMOCAP data set tested a multimodal model for emotion recognition. The total accuracy of recognition of their proposed

model has been improved by 10.05% & 11.27% respectively compared to a single modal of speech & face expression. [26].

J. Awatramani and N. Hasteer (2020) The work of this research shows that children with ASD are trained to detect human emotions using & implementing the fundamental architecture of CNN. A model has been validated using an existing literature data set, with an accuracy of 67.5%. [27].

Y. Maeda et al. (2020) In this study they propose a method of deep learning to categorize emotions of human facial pictures & to create robot emotional reaction by the emotions of the Markov model. They operate here to learn human facial pictures using CNN, which is a type of deep learning, with different emotional features & to identify the human emotions in human interactions. A robot returns its emotional behavior to humans on basis of the human emotion received via deep learning. In this research, an interaction experiment was performed with an actual communication robot & this outcome is also presented here [28].

Table 2: Comparative Study of Literature Survey

Year	Author's Name	Title	Technique	Outcome
2018	K. Tsai, J. Ding and Y. Lee	Frontalization with Adaptive Exponentially-Weighted Average Ensemble Rule for Deep Learning-Based Facial Expression Recognition	Advanced neural CNN	Simulations on various datasets reveal that the system proposed outperforms state of art FER approaches & may well detect a person's expression
2019	J. -H. Kim, B. -G. Kim, P. P. Roy and D. -M. Jeong	Efficient Facial Expression Recognition Algorithm Based on Hierarchical Deep Neural Network Structure	Hierarchical deep learning	A finding of 10-fold cross-validation demonstrates 96.46% of the preciseness in the CK+ data set and 91.27% of the precision in the JAFFE data set. Up to 7% of accuracy in JAFFE data sets is improved & the average increase is confirmed by around 1.5%
2019	S. Lin, Y. Tseng, C. Wu, Y. Kung, Y. Chen and C. Wu	A Continuous Facial Expression Recognition Model based on Deep Learning Method	Deep learning technique	analyze & detect continuous face expressions over some time to enhance conventional image recognition technique
2020	P. Kaviya and T. Arumugaprakash	P. Kaviya and T. Arumugaprakash	Deep learning technique	For FER-2013 & 60% for custom data sets, the proposed model obtains a final accuracy of 65%
2020	P. Babajee, G. Suddul, S. Armoogum and R. Foogooa	Identifying Human Emotions from Facial Expressions with Deep Learning	Deep learning method	The outcomes of their work show an accuracy of 79.8% to identify all 7 fundamental human emotions without using optimization methods
2020	L. Cai, J. Dong and M. Wei	Multi-Modal Emotion Recognition from Speech and Facial Expression Based on Deep Learning	CNN & LSTM	The total accuracy of recognition of their proposed model has been improved by 10.05% & 11.27% respectively compared to a single modal of speech & face expression.
2020	J. Awatramani and N. Hasteer	Facial Expression Recognition using Deep Learning for Children with Autism Spectrum Disorder	CNN	A model has been validated using an existing literature data set, with an accuracy of 67.5%
2020	Y. Maeda, T. Sakai, K. Kamei and E. W. Cooper	Human-Robot Interaction Based on Facial Expression Recognition Using Deep Learning	Deep learning	operate here to learn human facial pictures using CNN, which is a type of deep learning, with different emotional features & to identify the human emotions in human interactions.

VI. CONCLUSION

The facial expression of emotions defines a person's condition, mood, & present feeling by nonverbal communication. If we examine the emotions of a person at different stages, we may understand them. The percentage of emotions varies considerably at various phases. This paper presents an overview of facial expression recognition systems & different investigations. These systems include face recognition, extraction & classification of features. For good recognition rates, many approaches may be used. Higher recognition rate approaches are greater performance. These techniques provide practical solutions to the issue of recognition of face expression & may work properly in restricted environments. Recognition

of the human facial expression is one of the most powerful & challenging tasks in social communication. Face expressions are usually natural & direct means for humans to transmit their emotions & intentions. The essential features of non-verbal communication are facial expressions. This paper reviews research work carried out & published in the area for recognition of facial expression & different methods used for recognition of facial expression.

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