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# Human Emotion Recognition from Facial Expressions - A Review

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**ABSTRACT:** Emotion plays a significant role in everyday life and can be expressed in a variety of ways. A popular, efficient, and non-verbal technique of communicating emotion is through facial expression. In today's era, emotion recognition based on facial expressions has attracted a great deal of research interest. Emotion recognition from facial expressions is growing rapidly among both industry and academia, as it has the potential to be employed in a variety of fields. This paper reviews the various approaches adopted for recognition of human emotions from their facial expressions. The paper provides the information about the various datasets, algorithms and methodologies, various applications of emotion recognition and finally reveals the comparative results.

**KEYWORDS:** Artificial Intelligence, Convolutional Neural Network, Deep Learning, Emotion Recognition, Facial Expressions, Facial Emotion Recognition (FER), Human Emotions, Machine Learning.

## I. INTRODUCTION

Feelings are the most significant factor that distinguishes humans from machines. Humans rely on their feelings to communicate their reactions to others [8]. Human emotions are the most universal way of communication [7]. An emotion can be defined as a subjective and private physiological and mental condition that encompasses a wide range of behaviours, acts, thoughts, and emotions [6]. In other words, the appearance or reflection of a feeling is referred to as emotion. One of the most important aspects of effective communication is emotions. Emotion is a key topic in a variety of domains, including biomedical engineering, psychology, neurology, and health [15]. Images, pictures, audio, video, and body language can all be used to identify emotions [21]. Humans are capable of communicating with one another in a variety of ways. Some of the approaches used to determine the human emotional states are depicted in Fig. 1.

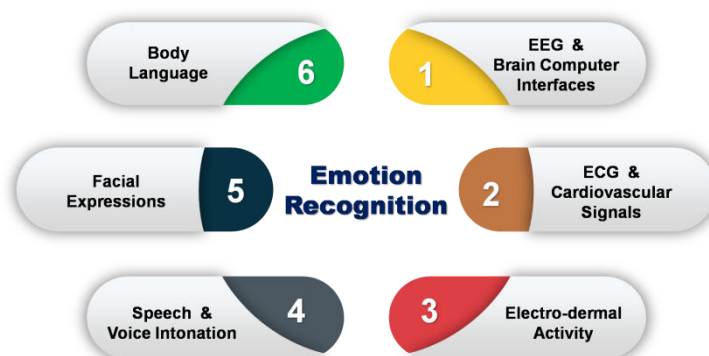
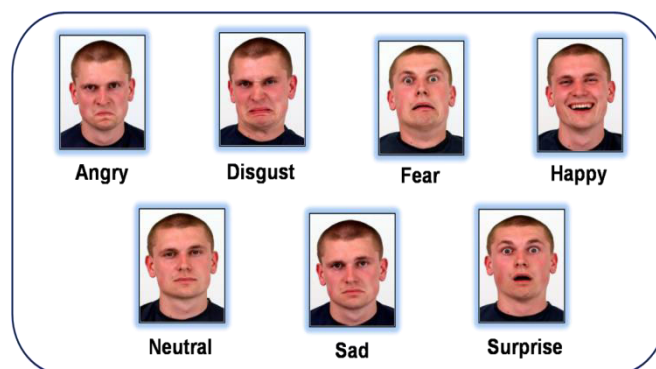


Fig. 1: Approaches of Emotion Recognition

Facial expressions are a form of non-verbal communication. Facial expressions indicate small changes in the facial muscle movements, and detecting and representing them can be a challenging task [2]. The process of recognising human emotion based on facial expressions is known as Facial Emotion Recognition (FER). FER is mainly based on face images [3]. Humans are born with the ability to recognise emotions. In fact, even infants of 36 hours old may deduce certain basic emotions from facial expressions. This ability is considered as one of the most significant social abilities in elderly individuals [4]. Emotions are related to human facial expressions, and learning to portray them is a critical step toward achieving seamless human-machine communication. Facial expressions are important in understanding human emotions. In general, there are seven different emotional states such as angry, disgust, fear, happy, neutral, sad, and surprise [5], which are depicted in Fig. 2.

**Fig. 2:** Basic Human Emotions

An emotion is a sensible mental reaction that can be felt as a strong feeling toward a certain thing. Physiological and behavioural changes in the body are usually associated with emotions [21]. Facial emotion recognition has been a major topic in research since 1990s, and according to its importance, it has played a significant part in image processing. FER has three primary steps: face detection, feature extraction, and emotion recognition; where each step employs a different algorithm [11]. FER processes and interprets the face image features to identify the human emotions. FER has a wide range of applications, including the service industry, criminal investigation and interrogation, medical assistance, and so on [17].

Artificial intelligence (AI) has made a significant contribution to the technological world. Machine learning and deep learning algorithms have achieved great success in various applications, because traditional algorithms have failed to meet human needs in real time [18]. The recognition of facial expressions that convey human emotions can assist computers in better assessing the human state of mind, allowing for more personalised interactions [19]. In facial expressions, information is dispersed over different parts of the face that includes eyes, cheek, mouth, eyebrows and forehead [21]. With the advent of big data and high performance devices, the deep learning has become widely employed in a variety of applications, including image classification, segmentation and recognition [22].

The objective of the paper is to provide a review of various methodologies adopted for the recognition of facial emotions of human. The rest of the paper is organized as follows: Section II provides the literature survey; Section III presents the comparative results of previous studies; Section IV briefs on the applications of emotion recognition; and lastly the Section V concludes the paper.

## II. LITERATURE SURVEY

Facial emotion detection is the subject of multiple research articles, and several problem solvers have expressed interest in recognising human facial expressions in recent years. This is due to the large range of applications in today's world in this demanding and challenging area.

Austin Nicolai et al. [1] introduced a fuzzy logic-based technique that included two stages: image processing and emotion identification. In the image processing stage, the face and facial characteristics were acquired, and then relevant points were extracted from each face characteristic. In the emotion identification step, the associated points were used to assess and then to determine the quality of various face actions. These characteristics were then used to examine how people expressed emotions. The experiment was conducted using the JAFFE dataset with an accuracy of 78.8%.

The paper presented by Tak-Wai Shen et al. [2] assesses the Light Field Camera's ability to recognise facial expressions. The light field camera first collects a new face expression dataset. To encode these facial components as features, the depth map was computed and then applied to the Histogram Oriented Gradient (HOG). The facial expression categorization was then performed using a linear SVM. Then the performance was evaluated using a new dataset with an estimated depth map.





The methodology adopted in paper [3] collects 1347 3D facial points using the Kinect V2.0. Then number of key facial points was identified, and feature extraction was carried out. For feature dimensionality reduction, Principal Component Analysis (PCA) was used. Emotion recognition models were built using a variety of classical classifiers like Decision Tree, Support Vector Machine (SVM), Random Forest, Random Tree and BayesNet.

In paper [4], deep Convolutional Neural Networks (CNNs) were utilized that can accurately interpret semantic information available in faces in an automated manner. Different loss functions and training tricks were employed to train CNNs with a high classification rate. The study was carried out using the FER-2013 dataset. The algorithm developed by Sanghyuk Kim et al. [5] was based on machine learning approach, which involved two important steps: face detection and facial expression recognition. The Haar features were obtained in face detection step, whereas HOG features were obtained in facial expression recognition step. The SVM classifier was utilized to identify the emotions which yield F1-score of 0.8759.

The paper presented by Shivam Gupta [6] accomplishes the emotion detection in both real-time and static images. The Cohn-Kanade Database (CK) and the Extended Cohn-Kanade (CK+) database were used for testing on static images, where as the webcam was used for the real-time testing. Initially face detection was done using HAAR filter, then the facial landmarks were identified. Then using facial landmarks the datasets were trained using the SVM algorithm and then classification was carried out. With SVM classifier, the accuracy found was around 93.7%.

Munasinghe's [7] methodology was to use the facial landmarks to identify the human facial emotions. The model was trained on the iBUG 300-W dataset before it was being used to recognise face landmarks. The CK+ dataset was used to train the random forest classifier and then system performance was assessed. The image manipulation tasks were accomplished with the aid of Python and OpenCV, and finally an accuracy of 90% was obtained. The study carried out by Manish Bhatt et al. [8] presents the facial expression recognition with the aid of geometric maps representation of the lips portion by using SVM classifier. The experiment was conducted on the CK database and it yields 94% accuracy.

The paper [9] represents emotion recognition using facial expression by detecting the face in videos and extracting the facial landmarks to form the geometric-based features to distinguish between various emotions for videos from BioVid Emo database. The different machine learning classifiers were adopted like random forest, SVM, K-Nearest Neighbors (KNN), and recurrent neural network (RNN). Finally, classification was carried out to produce different discrimination rates for the human emotions.

The methodology proposed by Divya Mangala et al. [10] was to recognize the facial expressions of human being by using Eigen Faces. Face detection, feature extraction and classification steps were considered for the recognition of human expressions. The study uses Principal component analysis for face recognition and it was relying on calculating the Euclidian distance for the Eigen Faces. Total 50 facial expression images were considered and then trained by using the Eigen Faces. Finally the featured Eigen Faces were compared with the test image and accuracy was calculated.

The paper [11] presents an automatic system for facial expression recognition. The CK+ dataset was used to carry out the validation phase. The study uses Viola-Jones algorithm for face detection, HOG was used as a descriptor for feature extraction and PCA was applied to reduce the dimensionality of the features. Three different classifiers were utilized such as SVM, KNN and Multilayer Perceptron Neural Network (MLPNN) for classifying the facial expressions. The experimental results showed the recognition rate of 93.53% (SVM), 82.97% (MLP) and 79.97% (KNN).

Bendjillali Ilyas et al. [12] proposed a method that included the Viola-Jones framework, histogram linearization, Discrete Wavelet Transform (DWT) and deep CNN. The input to the deep CNN was extracted facial characteristics obtained from DWT. Then CNN network was trained using these characteristics. The study was carried out on two datasets: JAFFE and CK+, which had accuracy of 98.43% and 96.46%, respectively. In paper [13] CNN was used for training over gray scale images obtained from fer2013 dataset. The experiment was carried out with different depths and max pooling layers and finally achieved an accuracy of 89.98%. Performance was evaluated using shallow network and modern deep network. The real-time implementation of emotion recognition was carried out using web-camera.

Muhammad Rusydi et al. [14] used the CK+ dataset to determine the distances and regions formed by the facial points in order to identify the emotions with a final accuracy of 75%. In study [15] Convolutional Neural Network was proposed based on LeNet architecture for facial expression recognition. The study combines 3 datasets like JAFFE,

KDEF and custom dataset. Then LeNet architecture was trained for emotion classification with training accuracy of 96.43% and validation accuracy of 91.81%. In paper [16] Zhou Yue et al. designed a modular multi-channel deep convolutional neural network. The network output uses a global average layer for avoiding overfitting and the performance of network was tested on the FER2013 dataset with accuracy of 68.4%. By using the trained recognition model, a real-time facial emotion recognition system was built.

In paper [17] author proposed a high-performance facial expression recognition method based on facial action unit. The methodology was mainly divided into two parts. In the first part, 68 facial landmarks and image HOG were obtained, and then feature values of action units were calculated. The second part uses three classification methods to realize the mapping from action units to FER using CK+ and Oulu CASIA datasets. The main focus of the paper [18] was to create a Deep CNN model, which classifies five different human facial emotions. The model was trained, tested and validated using the manually collected image dataset and finally it yields a testing accuracy of 78.04%.

Phavish Babajee et al. [19] explored the recognition of human facial expressions through a deep learning approach using a CNN algorithm. The system comprised of a labelled data set with 32,298 images with multiple facial expressions for both training and testing. The pre-training phase involved face detection with noise removal including feature extraction. Then trained model was used for prediction of emotions that had an accuracy of 79.8% for the recognition of all basic seven human emotions. The convolutional network developed by Akriti Jaiswal et al. [20] shows how to construct an artificial intelligence system with three stages: face recognition, feature extraction, and emotion classification. The study used two datasets: FER-2013 and JAFFE that produced accuracy rates of 70.14% and 98.65%, respectively.

In paper [21], the human group facial emotion recognition system was proposed using a deep learning approach. The framework used the Haar filter to detect and extract facial features. Then the CNN was designed to recognize facial expressions and to classify them. Finally, the predicted group emotions were fed into an audio synthesizer to obtain an audio output. The final accuracy of 65% and 60% were achieved using FER-2013 and custom datasets respectively. Xu Xu et al. [22] presented a novel method for fully automatic facial expression recognition. The facial landmarks were detected for characterizing facial expressions. A graph CNN was proposed for feature extraction and FER classification. The experiments were performed using JAFFE, FER2013 and CK+ databases. The study achieved an accuracy rate up to 95.85%. Lakshmi Videla et al. [23] developed a network based on a ten-layer vanilla CNN that can automatically find the prominent features without the need for human. The JAFFE and CK+ datasets were used that produced an accuracy of 78.1% and 99.3%, respectively.

### III. COMPARATIVE RESULTS

The Table 1 provides the comparative experimental results of the literature carried out for the recognition of human facial emotions.

Reference	Dataset Used	Algorithm	Emotions Detected	Accuracy Rate
[1]	JAFFE	Fuzzy Logic	Angry, Disgust, Fear, Happy, Sad & Surprise	78.8%
[2]	Self-Prepared	Support Vector Machine (SVM)	Angry, Disgust, Fear, Happy, Neural, Sad & Surprise	---
[3]	Self-Prepared	SVM, Random Forest, Random Tree & BayesNet	Happy, Neutral & Sad	80%
[4]	FERC-2013	Deep CNN	Angry, Disgust, Fear, Happy, Neural, Sad & Surprise	71.9%
[5]	Self-Prepared	SVM	Angry, Happy & Neutral	87.59%
[6]	CK & CK+	SVM	Angry, Contempt, Disgust, Fear, Happy, Neural, Sad & Surprise	93.7%
[7]	CK+	Random Forest	Angry, Happy, Sad & Surprise	90%
[8]	CK	SVM	Angry, Disgust, Fear, Happy, Sad & Surprise	94%
[9]	BioVid Emo	Random Forest,	Angry, Disgust, Fear, Happy & Sad	82%

		SVM, KNN & RNN		
[10]	Self-Prepared	PCA	Angry, Disgust, Fear, Happy, Neural, Sad & Surprise	98.5%
[11]	CK+	SVM, KNN & MLP	Angry, Contempt, Disgust, Fear, Happy, Neural, Sad & Surprise	93.53%
[12]	CK+ & JAFFE	Deep CNN	Angry, Disgust, Fear, Happy, Neutral, Sad & Surprise	98.43%
[13]	FER-2013	CNN	Angry, Disgust, Fear, Happy, Neutral, Sad & Surprise	89.98%
[14]	CK+	Artificial Neural Network (ANN)	Angry, Disgust, Happy & Surprise	75%
[15]	JAFFE, KDEF & Custom Dataset	CNN	Angry, Disgust, Fear, Happy, Neutral, Sad & Surprise	96.43%
[16]	FER-2013	CNN	Angry, Disgust, Fear, Happy, Neutral, Sad & Surprise	68.4%
[17]	CK+ & Oulu CASIA	SVM, Extreme Gradient Boosting & Deep Neural Networks	Angry, Contempt, Disgust, Fear, Happy, Neural, Sad & Surprise	---
[18]	Self-Prepared	Deep CNN	Angry, Happy, Neural, Sad & Surprise	78.04%
[19]	FER-2013	CNN	Angry, Disgust, Fear, Happy, Neutral, Sad & Surprise	79.8%
[20]	FERC-2013 & JAFFE	CNN	Angry, Disgust, Fear, Happy, Neutral, Sad & Surprise	98.65%
[21]	FER-2013 & Custom Dataset	CNN	Angry, Happy, Neutral, Sad & Surprise	65%
[22]	JAFFE, FER-2013 & CK+	Graph CNN	Angry, Disgust, Fear, Happy, Neutral, Sad & Surprise	95.85%
[23]	CK+ & JAFFE	Vanilla CNN	Angry, Disgust, Fear, Happy, Neutral, Sad & Surprise	99.3%

**Table 4:** Comparison with Previous Work

#### IV. APPLICATIONS

Emotion identification from human facial expressions has several applications in various disciplines which are discussed below:

- ✦ FER is an area of investigation in computer vision which has been extensively investigated because of its specific applications in human-computer interaction, medical assistance, and virtual reality [5].
- ✦ FER can be used to assess a person's mental state, such as when driving. In particular, motion slowness caused by fatigue is linked to traffic accidents, and driver fatigue may be anticipated using driver's facial expressions [5].
- ✦ In the near future, emotion recognition will be very important in the field of robotics and artificial intelligence. For example, if a robot can recognise any human's emotion and respond appropriately without the help of other people. Thus it could be helpful to improve human-robot interactions [6].
- ✦ The FER could be useful for automobile fatigue detection systems, entertainment systems like gaming, clinical depression identification systems, pain assessment [7].
- ✦ Institutions and businesses can also adopt FER as a useful tool for teaching their staff and constituents about anger control practises. It will eventually benefit them to improve their organization's reputation, morale, and to reduce absenteeism, as well as to treat socio-emotional difficulties among their employees [9].
- ✦ FER can be utilised in a variety of applications including criminal identification and system security [10].
- ✦ FER has applications in fields like artificial intelligence, military and police services [11].



- ✦ Emotion recognition could aid in the diagnosis of mental and behavioural abnormalities. Also it can be implemented for consumer behaviour analysis [15].
- ✦ Other applications includes: virtual reality, cognitive science, and personality development [22].
- ✦ FER could be useful to analyse students' interest in a classroom [23].

## V. CONCLUSION

Emotion plays a significant role in determining the thoughts, behaviour and feeling of a human being. The recognition of human emotions has caught the curiosity of many problem solvers. The expressions on a person's face reveal a lot about their cognitive process and provide insight into what's going on inside their heads. From the brief survey of human emotion recognition from facial expressions, it is concluded that FER will going to play a significant role in future in various sectors.

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