A Survey on Facial Expression Recognition using Machine Learning Techniques

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Abstract— **In recent years, many researchers are taking an interest in the research area of Face recognition due to its diverse applications such as security systems, medical systems, entertainment. Nowadays, many kinds of biometric information processing systems are used for various purpose face-recognition systems. The facial expression that can define the human mental state and behavior and it is used for security purpose. FER is used in domains such as healthcare, marketing, environment, safety and social media. This paper presents the survey of the facial expression recognition system that includes the four main stages i.e. face detection, pre-processing, extraction of features, and classification. This research provides a broad overview of the FER process includes all stages of FER system as well as the various methods used to evaluate the efficiency of the various methods of facial expression recognition. This survey paper also helps to understand the approaches, different techniques that address and analyse the problems and challenges comes in the real-time environment. Finally, this paper concludes the state-of-the-art and explore the challenges faced in implementation of FER process along with the scope of future development.**

Keywords— **Face Recognition, Facial Expression Recognition (FER), Image Processing.**

I. INTRODUCTION

Interaction between human and computer (HCI) plays a significant role in regular activities. We are entering a generation where all activities are carried out from home via PC in place of handwritten documents. Biometric data and face detection are the two main areas in which HCI research is going. The human emotions can be classified by a psychological characteristics such as facial expressions, voice, the hand gestures, the movement of body parts, the variation in heartbeat and blood pressure. The psychologist Albert Mehrabian's "7 – 38 - 55 rule" 7% of the message is transmitted through verbal language as face-to-face communication, 38% of the message is transmitted through speech, and 55% of the message is transmitted through facial expressions. Research by Ekman and Friesen suggests that facial expressions are ubiquitous and inherent. Facial expressions convey the thinking of an individual and form a type of non-linguistic interaction that is very powerful. There are six basic expressions of the face, including surprise, smile, sorrow, rage, fear, and disgust.

The expression of the human face relies on skeptical entities like mind, facial muscle, condition, surroundings. Recognition of facial expression can generally be defined as the method of defining the human mental state or the emotions of evaluating the motion of facial components, like eye blinks, the movement of lip counts, skewed eyebrows, thin and extended eyelids, pulling down eyebrows and creasing nose.

Researchers are publishing different characteristics of different algorithms and methods to distinguish a face from the fixed and variable image frames. Several researchers have developed different feature extraction methods for analyzing facial expression after face detection. Most research is conducted in the field of FER techniques comprise in the four stages: face detection, image preprocessing, feature extraction and classification of expression. For the implementation of FER techniques, researchers use various datasets.

This survey paper, various stages of facial expressions are analyzed and explain in brief with the different algorithms used to identify six basic expressions. Facial expression recognition is split into Four major stages detection of the image from a background, preprocessing of image feature extraction and categorization of expression. We addressed the latest methods for FER detection and extraction of features and described the real-time applications as well. This survey provides the latest techniques for facial expression recognition. This paper also covers the challenges faced by researchers such as illumination, the variation in pose or head movement, complex backgrounds, etc.

The process of FER is divided into four phases, which is shown in block diagram [8]:

A. Face detection,
B. Pre-processing of the image,
C. Feature extraction process,
D. Classification.

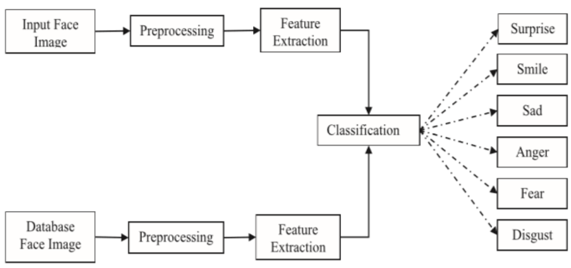

Fig. 1: Block diagram of the FER process

A. FACE DETECTION.

The method of facial detection is to isolate the facial region from the context of a picture or video. To identify expressions, input images with different illumination conditions and complex backgrounds may be confusing. Face detection involves segmentation and extraction of uncontrolled facial features. The various methods of face detection are accessible, such as the eigenspace method, the adaptive skin color method, and the Viola-Jones method. Under variable pose conditions the eigenspace method has high accuracy of face detection, but the head movements permitted movement only in the same plane, an adaptive skin color method has high accuracy in the identification of skin complexion, but it affects by illumination, an adaptive gamma correction method is used to reduce the above effect. In the Viola-Jones process, the haar classifier is used to improve the recognition level by increasing computation and complication costs during the test phase. Adaboost is commonly used because of its improved accuracy and relatively low computational complexity. Adaboost's main drawback is its vulnerability to noisy data and outliers [23]. Face detection using contour points gives high accuracy and reduces computational cost. The research is to identify accurately the faces and their about the accurate identification of faces and the high rate of recognition under a controlled and uncontrolled environment. [1]

At this stage, a software identify the face first and split the captured area of the face into three primary components to remove additional boundaries in the image, like hair, chin, skin detection, and segmentation.

B. PRE-PROCESSING

Image preprocessing is used to improve the FER system's performance which involves various kinds of procedures like image visibility and scaling, contrast-correction and extra improvement procedures to enhance the expression frames.[16]. Therefore, an effective preconditioning of the image is important for achieving higher recognition rates, using effective preconditioning algorithms allows the OCR system more reliable, primarily through accurate image enhancement, noise elimination, , etc.

C. FEATURE EXTRACTION PROCESS

Features extraction is the next phase of recognition of facial expression. The main goal of extraction of features is to achieve an effectual presentation of facial parts without compromising the image quality. For further processing, the extraction of the function is used to find and depict beneficial characteristics of interest within an image. The methods of extraction of features are classified into five kinds, like techniques based on texture, edge, global and regional feature, geometric feature, and patch. The natural features are always present on the face, but maybe disturbed during the change in expressions is called geometric features, e.g. Eyes, Eyebrows, Mouth, Tissue Textures, and Nose. The temporary feature appears during the change in expression is called appearance features like various types of wrinkles, bulges, foreheads, mouth and eye areas. [17].

Eigen faces also known as Karhunen-Loève expansion, and it is the most thoroughly researched method Eigen picture, eigenvector, and a principal component. The main component analysis was used to depict the face accurately using the low-level technique to identify the human face.

D. CLASSIFICATION

It is the final stage of the FER scheme in which the classifier uses both parametric and non-parametric methods to categorize expressions like smile, sorrow, surprise, anger, fear, disgust and neutrality. To achieve the highest recognition level, several classification algorithms have been developed. Besides, not all methods are appropriate for examining various techniques of extraction of facial features. To create an efficient real time FER technique, a dataset with various spontaneous expressions is required. In the classification process, the classifier compares processed the image with the trained database by using different classifier like SVM, neural network, Adaboost, eigenfaces, logistic regression, decision tree, the nearest neighbour, hidden Markov models, etc. [1]

E. DATASETS

Experiments are conducted on FER system multiple databases likely to be Japanese Female Facial Expressions (JAFFE, 2017), Cohn – Kanade (CK, 2017), Extended Cohn – Kanade (CK+), MMI (MMI, 2017), Multimedia Understanding Group (MUG, 2017), Taiwanese Facial Expression Image Database (TFEID, 2017), Yale (Yale, 2017), AR Face Database (AR,2018), Real-time Database (Zhao and Pietikäinen, 2009), Own database (Siddiqi et al., 2015) and Karolinska Directed Emotional Faces (KDEF, 2018). Here we discuss in brief some datasets of facial expression.

1. JAFFE dataset: The JAFFE datset [5, 7, 13, 23, 31] is extensively used as a dataset composed of 60 Japanese women's images of gray frontal facel expression. It contains 213 pictures in total, including seven face expressions such as happy, sad, fear, anger, disgust and surprise along with the neutral face with the resolution of the image of 256 x 256 pixels

2. CK dataset: The authors [6, 8, 23] provides a group of 300 images from the Cohn-Kanade AU-Coded Facial Expression Dataset. The CK dataset comprises 486 video sequences with successful displays to the maximum from 97 subjects. The extended version (CK+) comprises 593 posed sequences of speech from 122 sequences of 66 subjects of the spontaneous smile.[11, 29]

3. MMI dataset*:* The MMI dataset contains more than 2000 videos and photos of 75 topics of basic expressions [15].

This paper also introduces different techniques to solve the issues of the FER system. The paper is structured as follows: a literature survey in Section II. Section III addresses the FER framework problems and challenges. Finally, in Section IV, we conclude the paper with Section V give the scope future research work in section VI.

II. LITERATURE SURVEY

Saranya Rajan et al. [1] provides a detailed study of FER methods, classificators and data sets used to evaluate the efficacy recognition methods. In this paper, they discuss the best approach for real-time applications without tradeoff quality and approaches to address issues such as subjectivity, lighting, occlusion, pose variance and dynamic context. Zhihong Zeng et al. [2], presents a review paper on multimodal sensor data aid automated facial expression recognition systems. They reviewed the latest FER systems and explained the methodologies and limitations in the wild environment. They provide multimodal sensor data with an integrated FER scheme and evaluate the theoretical feasibility and effectiveness of emotion detection. Javier Galbally and Sebastien Marcel [3] suggested a novel software-based fake detection approach that can be used to identify various kinds of fraudulent access attempts in multiple biometric systems In this research paper a novel security approaches are tested using readymade dataset with well - defined associated protocols on three commonly used biometric modalities such as iris, fingerprint and 2D head.

Guoying Zhao and Matti Pietikainen [4] has suggested a block-based technique which combines local pixel, area and quantity data to acknowledge particular dynamic occurrences like facial expressions in sequences. In the Cohn-Kanade Facial Expression Database experiments, the LBP TOPu2 8;8;8;3;3;3;3 feature provided an excellent recognition accuracy of 94.38% in the dual cross-validation. Combining this function with the VLBP3;2;3 resulted in further development, resulting in a double 95.19% and a 10-fold cross validation 96.26% respectively. Ji-Hae Kim et al. [5], presents an efficient FER algorithm incorporating appearance and geometric characteristics based on deep neural networks to make facial expression recognition more accurate and effective. They also developed a more flexible interface by integrating the appearance network's static appearance function with the geometric shape-based network's dynamic feature. Compared to the other algorithms in the CK+ dataset, they reached about 96.5% accuracy with 1.3% enhancement and 91.3% accuracy, enhanced by 1.5% compared to other current JAFFE dataset techniques. Jun Ou et al. [6] resented an automated FER system using visual C++, using Gabor wavelets to extract facial features and KNN to identify emotional facial expression. This technique is very efficient in achieving high efficiency, i.e. the average rate of recognition is 80% and it has enhanced 3%.

Nazil Perveen et al. [7] suggested the Facial Expression Recognition (FER) method, modeling support, facial expression space for FER points and Gini index In this paper they used a decision tree as classifier. Tha author used MATLAB tool for implementation. Naveen Kumar H N et al. [8], suggested using HOG features to make FER independent performance. The work's accuracy is found to be 92.56 percent when implemented for six basic expressions using the Cohn-Kanade dataset. In this paper, they compare the HOG features with LBP and geometric feature and the results suggest that the appearance and shape modeling of HOG is more appropriate for representing facial expressions. Douglas W. Cunningham and Christian Wallraven [9] use a high-quality facial animation device to analyze the significance of two types of visual information for strength perception and facial expression recognition. The author indicates that facial expressions have data distributed redundantly in multiple forms and can be encoded and integrated effectively.

XuMing Wang et al. [10] Use a CNN + SVM template, facial expression recognition algorithm and pre-processing image. They achieve 68.79% accuracy in recognition of facial expression. Snehasis Mukherjee et al. [11], suggest two motion descriptors and applied to recognize facial expressions. The suggested method performed the latest approaches in terms of recognition accuracy. Tobias Gehrig and Hazım Kemal Ekenel [12] carry out automated emotion classification tests that have at best achieved a right classification rate of 29.81 percent (increased by 7.06 percent) on the testing stage using Gabor features and web-trained linear support vector machines.

Lutfiyatul Fatjriyati Anas et al. [13] proposed that the FER technique will be identified the face expressions via webcam and image for expression likes and dislikes. In this paper a method was created to find out what a person sees or judges an object, in particular fashion images, by expressing a human face while looking at a fashion image.. Gozde Yolcu et al. [14], introduced a deep learning model for automatic facial expression recognition. These tests achieved accuracy of recognition of facial expression by 93.43%, increased by 6% over recognition of facial expression from the unprocessed image. Sina Mohseni et al. [15], introduces a noval descriptor for accurate recognition of facial expressions. In this paper, by extracting geometric characteristics from salient facial sections, we examine facial expressions. In this article, we use the graph edge ratio in place of calculating displacement, which creates errors due to head orientation.

Tak-Wai Shen et al. [16], suggested an active solution with the light field camera to deal with the issue of facial expression recognition. The experiment performed on the dataset shows the light field camera's improved efficiency, which can be attributed to its ability to render deep data. Zankhana H. Shah and Vikram Kaushik [17], the canny edge detection results are an effective technique for extraction of features for the purpose of recognition of face expression. They concentrate on objects with different illuminations and evaluate with two classifiers the output of the canny edge detection technique.

YijunGan Ball [18] for facial expression recognition, they implemented CNN with four separate architecture (e.g. GoogleNet, ResNet, VGGNet and AlexNet). In this paper, the researcher found that the best overall accuracy was obtained by AlexNet i.e. 0.6424. Zhang Nan and Geng Xue [19] clarify the identification of face expression based on local facial regions. Pictures of the local facial components are known to be obtained by the manual cutting of four local areas like the mouth, the nose, the eyes (including eyebrows) and the mesophryon. In this research paper, the expression recognition level of the mouth area and the eye area is lower than the entire face. Washef Ahmed et al. [20], contributes to recognize blended phrases and the confusion inherent in the video. They proposed in this paper the fully automatic identification of fundamental face expression in the presence of variation in the pose along with the measurement of expressive frequency accompanied by quantification with a score. Human psychovisual assessment validates the performance of the scheme. The proposed scheme can be used in the therapy of mental sickness and dipression (like patients with low IQ autism) by using psychological techniques intended to promote conflict communication and problem understanding.

Chongliang Wu et al. [21] suggest a fundamental bilateral learning approach to understanding of expression recognition. Visible and thermal facial image are presented as two views of images in this article. In order to help understand thermal image data are used as privileged information to convey visible image data. Kiran Talele et al. [22] involves the comparison and evaluation of the partitioning of the object frames to further enhance the recognition performance using the effective LBP extraction function technique. They checked the system performance with the block size 64 x 64 pixels in this paper is higher than the other block sizes. Dong-Ju Kim et al. [23] proposed to use the ASM-based face alignment and EHMM to recognize facial expression In this paper, they conducted an experiment to check the performance of the proposed approach, the CK facial expression dataset and the JAFFE dataset, and the result shows that the proposed technique has better quality identification than other technique.

Hyung-Il Kim et al. [24] introduced a robust and reliable FR framework FIQ evaluation. In this paper, they suggest that FR systems with the proposed FIQ evaluation method can improve the accuracy of face recognition. Amol S Patwardhan [25] use continuous multimodal audiovisual information to detect psychological duality and mixed emotional experience automatically. Coordinates, length, and tracking point motion were used to create visual input characteristics that recorded facial expressions, eyes, hand gestures, and body movement. In this paper, they developed 3D characteristics from behavioral patterns based on co-ordinates, locations, movement and awareness. The combined function vector was then used to classify mixed emotions simultaneously.

Georgia Sandbach et al. [26] suggest that the development of 3D data acquisition methods has facilitated the establishment of several databases, especially in static analysis. Maja Pantic and Ioannis Patras [27] proposed a novel approach for detecting AU based on changes in the location of the facial points monitored in a video showing a close-up view of the head. In this paper, the proposed approach for encoding 27 AU codes and their combinations in 119 test samples is an average recognition rate of 86.6%, whereas the AFA template for encoding 16 AUs and their combinations in 113 test samples is reached to an average recognition rate of 87.9%. Gaetano Valenza et al. [28] implement an adaptive multi-class arousal / valence classifier comparing output when non-linear model extracted features are used as an alternative to standard features.

Yongqiang Li et al. [29] proposed a hierarchical model for simultaneous facial tracking and face expression recognition, based on the Dynamic Bayesian Network. In this paper, we present systematically depicting and modeling interrelationships between different levels of facial behavior, as well as data on temporal evolution, the suggested model achieved significant improvements in both facial control and AU recognition compared to the latest technique. Mei Wang and Weihong Den [30] provide a comprehensive survey of deep FR from two data and algorithms is provided. The methods of face processing are introduced in this paper and categorized as "one-to-many increase" and "many-to-one standardization." Lastly, deep FR special scenes, including face recognition video, 3D face recognition. R. Parthasarathi et al. [31] suggested a system of recognition of facial expression and some mixed expression (e.g. happiness and surprise, fear and disgust) using neural networks and PC

TABLE 1 PERFORMANCE ANALYSIS OF FER TECHNIQUES.

Author Name	Face Detection Techniques	Feature Extraction Techniques	Classiffier	Dataset	No. of facial expressions recognized	Recognition accuracy (%) & Recognition rate	Observations
Javier Galbally et al.[3]	Image Quality Assessment (IQA)	Sequential Forward Floating Selection (SFFS)	LBP, SVM	JAFFE, CK+	6	Recognition accuracy 96.5% with CK+ & 91.3% with JAFFE	An error rates achieved were less than those identified by other techniques
Jun Ou et al.[6]	Crop the image obtained by camera.	Gabor Filter	K-Nearest Neighbor	CK+	6	Recongnition rate is 80%	The efficacy of the extraction expression function depends entirely on the efficacy of raw image pre-processing.
Naveen Kumar H N et al. [8],	Viola Jones algorithm	HOG Feature Extraction	SVM	CK+,	6	Recognition accuracy 92.56%.	Rate of detection is less in case of disgust, fear and sad expressions.
XuMing Wang et al. [10]			CNN and SVM	FER, 2013	2	Recognition accuracy 66.59%	The stacking using SVM is an effective model ensemble method.
Lutfiyatul Fatjriyati et al. [13]	Dlib, dlib face detector	Dlib face landmark facial detection	K-Nearest Neighbor	JAFFE	2 {Like and Dislike}	-	There are undetectable expressions in some ID images because the system fails to identify the face of the user. While running

							slideshow, this technique fails to detect the number of user's face.
Sina Mohseni et al. [15]	Appearance features and Viola and Jones detector	Geometric features extraction	SVM	MMI	6	Recognition accuracy 87.7%	Extracting geometric features from specific facial components to examine facial expressions.
Vikram Kaushik [17]	DCT Normalization	Canny edge detection method,	Euclidian Distance & Neural Network	JAFFE, IFE	6	Recognition rate is 73% for JAFFE and & 76% for IFE	Canny edge detection tum is an effective technique for extracting features for FER system regardless of any kind of classifier
Chongliang Wu et al. [21]	Images obtained from visible cameras and thermal cameras	Canonical correlation analysis (CCA)	SVM	NVIE and Equinox	7	Recognition accuracy 95.48% For JFED, 94.25% for TFED, 94.91 for CKFED,& 94.81% for IFED	This system beats other approaches with the highest reliability of identification and F1-score.
Amol S Patwardhan [25]	Video channel used for 3D data and OpenEar toolkit used for audio data.	Human annotator	SVM	API and SDK	6	Recognition accuracy 96.6%	Multiple modalities can automatically detect simultaneous emotions or mixed emotions

IV. CHALLENGES

The researchers are faced different problems while implementing of FER system such as more emotions such as curiosity attentiveness and mixed emotions like sadness with anger, anger with disgust, disgust with fear, fear with surprise and surprise with sadness expressions.

Variation in illumination or brightness affects the feature extraction process which will further affect the performance of the FER system, Pose variation is another limitation with 2D automated facial expression recognition system. Most of the researcher work on 2D view or front face view or single pose, but due to the head movement which is frequently occurs in the image sequence. Very few researches are worked on 3D view or dynamic 3D recording and 4D view.

V. CONCLUSIONS

The researchers used different method at different stages like facial image detection, image preconditioning , feature extraction and classification, they used different dataset as per their findings. Few researchers used ready made dataset such as JAFFE, CK, CK+, MMI, MUG, TFEID, etc, and few used creates their own dataset. Several researchers adopted different approaches to collecting, extracting and classifying objects to create a robust FER system in real time. The state-of-the-art techniques in this study have concentrated to some degree on the regulated and unregulated environment. We also discuss approaches to address issues like subjectivity, enlightenment, occlusion, raise variability and nuanced history.

VI. SCOPE OF FUTURE RESEARCH.

In the future, We should extend the research of creating a FER program to recognise more expressions of other faces or symbols than basic expressions. For example, for real-time applications, fatigue, irritation, excitement, aggressiveness and so on support.

The current system uses available data sets that, when implemented in real time, restrict the performance of an illustrious thing. The available facial expression data sets are not only viewed on the front and preprocessed under the regulated environment. However, they still have objects and object sequences are of fixed sizes, making it easy for feature extraction, whereas in the real-time world it is not possible. In a real-time environment an appropriate new system should be built broadly from the baseline to deal with the current datasets.

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