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Facial Expression Recognition based on Hybrid Feature Extraction Techniques with Different Classifiers

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Abstract

Facial Expression Recognition (FER) became an important and interest challenging area in the field of computer vision. Due to its major application possibilities, FER is an active topic of research papers since the 1990s, also for the same reason, FER has accomplished a high role in the image processing area. Typically, FER is processed in three main stages including face detection, feature extraction or selection, and classification. This study presents an overview of the current work done for the techniques of the FER field and reviews some of the published researches for the last five years till the date. This paper also gives an overview of the customized made FER algorithms and focused on the method of feature extraction of these FER techniques also the databases that are used. The feature extraction techniques played an important role in making these algorithms more efficient.

Keywords: *face expression recognition, face emotion recognition, facial expression recognition, feature extraction.*

I. Introduction

Naturally, the expressions of a human face can be utilized in many identification tasks for emotional orientations, social interactions, and health qualities. In the present time, the technologies of Facial Expression Recognition (FER) are vastly used in the different fields of research such as computer games, driver fatigue detection, e-Learning, human-computer interface, and other emergent applications[1]–[5].In general, human facial expressions can be classified into seven basic expressions, neutral, anger, disgust, fear, surprise, sad, and happy. Accordingly, developing computer algorithms for recognizing facial expressions has become a popular topic. Basically, the technique of FER consists of three main portions including face tracking and detection, feature extraction of facial expression, and classification of facial expressions[6], [7]. Several improvements have been generated in the techniques of tracking and face detection and, the mechanisms of feature extraction and classification techniques[8]–[12]. For

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increasing the recognition rate many evolutionary algorithms such as fuzzy logic, neural network, data mining, deep neural network, etc. were incorporated with the algorithms of face recognition[13], [14]. During applying the corresponding algorithms, many constraints have been faced and implemented, like having changes with age, varying in poses, the differences in illumination, varying in expressions, etc. Breaking up even one constraint can be a great challenge. The algorithms that have a high rate of recognition for normal face may cause failure if used for recognizing a face with expression [2], [15], [16].

This paper reviews the various algorithms used in FER. The key factor is the descriptor in the method of FER. The efficiency and the productivity of FER rely on feature extraction method how much easy to extract features for the descriptor[17], [18]. For the different expressions, the descriptors could have high variance while for the same expressions may have no or little variance[14],[19],[20]. Typically, the methods of feature extraction in FER techniques are divided into two methods including the techniques of feature-based and model-based [17],[21]. The techniques of feature-based are also divided into geometric-based and appearance-based. The former uses the geometric parameters like pointers, curves, etc. for representing the different location of the image like eyes, mouth, nose, etc. also for estimating their relative position, width, etc. The later disposes the image

into pixel values instead of the feature shape components or relative estimations. Various pixel parameters are considered for representation like intensity, histogram, etc. Some algorithms perform the combination of both methods for getting better results.In this paper, some efficient techniques of FER are reviewed. Each technique used a specific algorithm such as Local Directional Number (LDN, Hybrid approaches, Histogram of Oriented Gradients (HOG), Linear Discriminant Analysis (LDA), Convolutional Neural Network CNN, Locality Preserving Projection LLP, Principle Component Analysis PCA, etc. Many databases were preferred for experimentation in each paper such as Yale database, Cohn Kanade database, CK+, JAFFE database etc.

II. The Process of Facial Expression Recognition

The mechanism of FER is processed in multiple phases. The major stages of FER are considered to preprocessing, face tracking and detection, facial part detection, feature extraction, and finally classification as shown in figure 1.

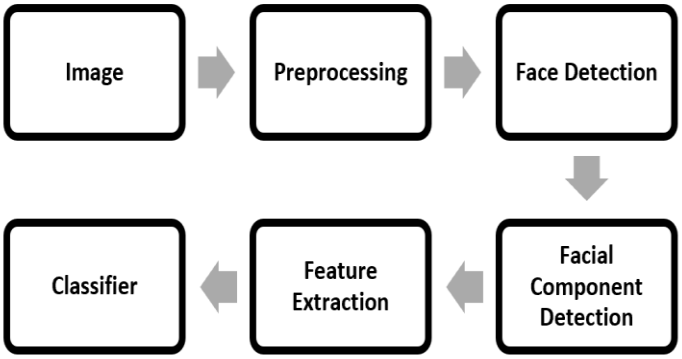

Figure 1. General Steps of Facial Expression Recognition

1. Preprocessing

The former step in any technique that includes image processing is preprocessing. Always considered as the first step for any techniques if image processing. This stage starts with making the input image consistent for preprocessing. This step is required because the image we get maybe is not in a standard form and it might be different in size and colour formats. Another reason, it might be affected by disruptions like noise, backgrounds, illumination variations, etc[22], [23]. Therefore, the preprocessing step is required for image standardization that includes noise removal, resizing, enhancement for the input image. Moreover, most of FER techniques utilize the input images with grayscale mode instead of colour

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mode, for that reason this transformation is also considered as a significant preprocessing step[24].

2. Face Detection

After the image has been preprocessed, the standardized image goes through the face detection stage for extracting the solo face and removing whole unwanted backgrounds. The widespread techniques used in face detection are Viola-Jones, Sobel, Edge detection, Canny, Kirsch, Prewitt, Laplacian, etc.

3. Facial Component Revealing

This phase consists of the tracking and detection of different regions of face which is called the region of interest (ROI). ROI includes eyes, forehead, eyebrows, mouth, lips, nose, ears etc. for ROI detection both global and local approaches are used.

4. Feature Extraction

The most important stage is feature extraction in FER. The FER efficiency is depended on the utilized techniques in this stage. The widespread techniques used in feature extraction are Local Binary Pattern (LBP), Principal Component Analysis (PCA), Gabor Filter etc.

5. Classifier

After extracting and preparing the most distinguished features from face images, the images are classified utilizing a particular classification technique to the appropriate class label of facial expressions. The widespread classification techniques are Deep Neural Networks (DNNs), support vector machines (SVMs), Neural Networks (NNs), etc.[25].

III. Literature Review

The efficiency and accuracy of FER system depends on the techniques and the algorithms of feature extraction and classification. Various techniques purpose. This section provides some techniques that have been utilized for the same purpose.

- A Facial Expression Recognition Based on Hybrid Techniques

Mannan et al. [26] proposed an automatic system utilizing an approach of a hybrid method for feature extraction which uses both appearance features and geometric features together for FER system that is counted as the best choice for feature extraction. Local Directional Number Pattern (LDNP) descriptor is used to extract appearance features while geometric features are considered the landmark point and their disposition of face. The unique work of this paper is proposing a coherence system by integrating some preferable reported methods for modalities fusion, machine learning, and feature extraction. See Figure 2. LDN descriptor was used for extracting the appearance features from the prominent regions only which are (eyes, nose, and mouth), the proposed regions are selected and extracted from the landmarks of face, jointly the face landmarks are also utilized for encoding geometric based features which are separate from LDN appearance features. In geometric approach, the features are extracted from several facial points and their displacement points. After features been extracted. The system used a PCA method for dimensional reduction in appearance feature because the dimensionality of appearance features was bigger than the geometric feature. Performing FER is done by using SVM classifier along with the decision level fusion. The method of this research is tested on CK+ dataset and gained a total recognition rate of 96.36%.

Natarajan and Muthuswamy[27] proposed a hybrid approach for FER system. For speeding up the processing of expression evaluation, pose estimation is executed before feature extraction for selecting an appropriate shape model. In order to position the point of face features, active shape model (ASM) is used and for Action unit's classification, Ada-Boost classifier is used, also for correcting the errors of Action Units, it uses Temporal Rule-based classification. This work has experimented on CK+ and FERT dataset, the

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experimental result shows that the provided method generates good performance with an average of 93.6%, 94.4% accuracy rate of five expressions for FERT and CK+ dataset respectively.

- Face Expression Recognition based on Principle Component Analysis (PCA)

Kumar and Garg [28] proposed an efficient approach for FER problem based on the gradient and PCA features. Authors declared that the gradient features are sensitive in the object distortion, so applying the gradient for encoding the facial components as features will provide accurate features. For validating the proposed method JAFFE dataset is used and trained by utilizing the random forest classifier for recognizing the facial expressions. In this work, PCA is used in the target of extracting the facial features into a group of determined feature descriptions as an Eigenfaces which are used for characterizing all type of faces. Authors in this work used a hybrid system of gradient filter, PCA and PSO and claimed that this hybridization generates better performance than the existing methods. The experimental results of this work show that the average recognition rate reached 91.3% on JAFFE dataset and this demonstrates the challengeable accuracy of the classification in their proposed method. Hernandez-Matamoros et al. [29] presented a new system for FER which provides an automatic system that detects and segments the origin facial regions of interest (ROI) into two regions which are forehead/eyes and mouth. The First step is extracting the face image by utilizing the algorithm of the face detection (Viola-Jones) algorithm. Next, the detected regions of face are fed to ROI detection phase for estimating the dimensions and for partitioning these regions into NxMblocks which are described by utilizing 54 Gabor functions, this function is correlated with all of NxM blocks. This method then used PCA for reducing the dimensions. The last step is inserting the outcome of feature vectors into the SVM classifier. The experimental results claimed that when the single ROI is used the proposed method reserves about 98% of recognition rate, but by concatenating all ROIs feature vectors which means taking the whole face, the recognition rate is increased to about 99%.

Fendri and Hammai[30] proposed an approach of face recognition under various expressions. Mutual information technique and LBP method are used for face detection and selecting the most significant regions of the face that are most responsible for appearing expressions, and this is helpful for reducing the vector size of features and for facial expression Classification. PCA method is used for dimensionality reduction to construct the Eigen Faces for each class of facial expressions. The experiment results were applied to two relevant datasets which are CK and JAFFE datasets. The accomplished outcomes demonstrated the significance of including the advancement of facial expression for achieving the face expression assignment without influencing the spatial-temporal involvement of the algorithm. Surely, authors prevailing with regards to achieving great face acknowledgment rates while radically decreasing execution time.

- Face Expression recognition based on Convolutional Neural Network (CNN)

Hamester, Barros, and Wermter[31] proposed a new system for FER based on the multi-channel convolutional neural network (MCCNN). The system is described by various channels (CNNs). Comparing with deep learning models, the proposed method can use fewer data and needs fewer efforts for training. The utilizing of two hard coded Soble based layers is one of the most important constraints of the MCCNN which is showing good outcomes if applied to a three topology canals. The provided system exchange both canals with a single canal as a Convolutional Auto Encoder (CAE) that is trained partially and unsupervised and another canal represents as a standard CNN and it remains

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the same. Information from both canals gathers in a completely connected layer which is then used for classification. For evaluating this system, two different experiments are implemented on JAFFE dataset which are leave-one-out and ten-fold section validation. After comparison with the previous method which used the feature extractor of hard coded sobel, the experiment results show the increasing in accuracy and decreasing in overall training time of an additional canal information with unsupervised learning.

Christou and Kanojiya[32] show the importance of machine learning techniques in increasing the FER accuracy rate. Therefore, proposed an approach based on CNN has been proposed for FER system. This approach is described and tested using FER2013 dataset which consist of human facial images with seven basic expressions. The experimental results show that the proposed approach can improve the FER system in accuracy rate to 91.12%. Schawn et al. [33] developed a lightweight FER application for the interaction of Human-Computer with TurtleBot units. The application is developed using the CNN method and an advanced algorithm of pre-processing according to the importance of the pre-processing step. This paper describes the combination of an algorithm obtaining the performance of state of the art by fine-tuning and utilizing the proposed methods. The overall target of this paper is by applying the algorithm of expression detection for HCI purpose. Also, this paper develops a client-server application and the Graphical User Interface GUI for enabling outsource of the intensive numerical calculations for remoting machine. The proposed pre-processing algorithm uses an affinable transformation to refine the small amount of obtainable face landmarks. AFEW, FER and CK datasets are used in this paper. The theoretic transmission is able to produce better results thought the difficulty of points acquiring. Using the recurrent neural network, the temporal information also is able to be included while the case of algorithm's use is video data.

- Facial expression Recognition based on BackPropagation Artificial Neural Network (BPANN)

Albakoor et al. [34] proposed a complex facial expression recognition method named FE8R by studying eight expression classes. This method is implemented based on the detection and selection of characteristic objects from the image by utilizing gradient transformation that depends on the assorts of minimal points and maximal points in each face region objects. Color FERET database and MUG Database are used for taking samples for experimental evaluation. The selected characteristic objects are calculated in two ways, the first utilizes slant tracking, and the second way incorporates BPCC based algorithm and Backpropagation Artificial Neural Network (BPANN) classifier based on feature encoding. The classification rate obtained 95% while the second method is confirmed to be fast and offering good results if compared to other methods. The proposed method flexible, unsupervised and provides high efficiency for recognizing various face expressions.

- Face expression recognition system based on PCA and LDA

Kar et al. [35] suggested an efficient method for FER based on a ripplet-II transform. Because of the efficiency of Ripplrt-II method in representing textures and edges, it is then used for extracting features from all those detected face images. In the next step, for obtaining a more discriminative and compact feature set PCA and LDA approaches are used. Classification is implemented utilizing a least-squares variant support vector machine (LS-SVM) and radial basis function (RBF) kernel. For validating the provided approach CK+ and JAFFE datasets are used. The experimental result shows that the provided approach produced better performance than other state-of-art to date. Kar, Babu, and Jena [36] again in another research proposed an automatic hybrid system for FER. The

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provided approach goes through four principal stages which are preprocessing, feature extraction, feature-length reduction, and classification. In the first step, the face is exposed using the face detection algorithm of viola and jones. Features are extracted using the intended descriptor which is named histograms of oriented gradients (HOG). In the third step the feature reduction is done by using PCA and LDA for obtaining the most significant features. Lastly, the obtained features are inserted into the BPNN classifier for an automatic determining facial expression recognition. For validating the proposed system CK+ dataset is used. The proposed system gained 99.51% of recognition accuracy using only six features. Varma, Shinde, and Shavan[37] proposed a FER system using both PCA and LDA techniques for feature extraction. An automatic system for classification of six facial emotions has been provided and evaluated based on two classifiers which are SVM and HMM. After testing the system on two different datasets Authors in their research ensured the significance of combining the features produced from LDA and PCA and that the combination demonstrated the efficiency and effectivity of this method in FER system. The experimental results of this research show the outperformance of SVM classifier over HMM classifier for all the other compare algorithms.

- Facial Expression Recognition System Based on Support Vector Machines (SVMs)

Rajesh and Naveenkumar[38] proposed a new system for real-time FER based on facial features and their actions. A special technique is utilized to recognize registered users and non-registered users. The images are taken from the CK+ database and PCA is used to reduce the dimensionality issue. For determining the different expressions of faces many different facial features are utilized. For recognizing and classification different expressions, the algorithms of machine learning are used by training of various set of images. For increasing the accuracy of both facial recognition and expression recognition, image number should be increased during the training time. For classifying a different emotion Multi-SVM classifier is utilized, one of them is used for training various class of expressions which is named –vs-All SVM, and another one is used for facial feature extraction which is named Dlib.

- Facial Expression Recognition Based on Deep Neural Nets

Das and Chakrabarty[39] presented a new approach for facial expression recognition using datasets of the face that consists of four expression classes (natural, happy, sad and angry) by applying the various neural network models and comparing their performance. The raw images are used without cropping the image and extracting features from the image. The raw pixels values are taken from all images in face images of CMU dataset. Representing the pixel values became at a higher level by supplying them into the Deep Belief Networks (DBM), Restricted Boltzmann machine (RBM) and Softmax Function with stacked Autoencoder (SM+SAE). The result shows that using SAE+SM is able to learn the recognition rate of 99.68% in both autoencoders with only 19 hidden nodes. Anywise, the recognition accuracy couldn't exceed 25.27% by varying the number of hidden nodes of DBN and RBM. For that reason, we determined that DBM and RBM are good for feature extraction but not for feature classification while SAE+SM is good in both feature extraction and feature classification.

- Facial Expression Recognition Using Improved Adaptive Local Ternary Pattern

Saurav et al. [40] presented a new improved descriptor of facial features called the enhanced adaptive local ternary pattern. It is the modified or improved version of ALTP used for the purpose of FER system applications. Some improvement done for this descriptor is using a uniform pattern of

ALTP and reducing dimension using PCA for the purpose of recognition accuracy enhancement and processing speed of provided FER system. This research is performed using CK+, JAFFE, and FRD datasets. The expressions are classified using K-ELM classifier. The experiment results clearly show the efficiency and the utility of the developed ALTP descriptor.

IV. Discussion

Most of the researchers have depended on the CK+ and JAFFE datasets for experimenting their results. It is found that depending on these datasets perform good results and high recognition rate of facial expressions. Researchers in their work proposed a method for classifying five to seven basic expressions. Generally, almost all of the literature works achieved high recognition rate. Several techniques of feature extraction and classification have been utilized in the reviewed papers. From the literature, it is found that the most significant and compactable technique of feature extraction is PCA for providing the best distinguished facial features. Most of the researchers depended on PCA for improving their proposed method. Utilizing PCA descriptor along with other feature extracted could perform a very high rate of recognition [13, 15, 21, 22, 25-28]. SVM is chosen to be the best classifier in providing a high performance for FER systems [12, 15, 22, 26-28]. Table I shows the comparable descriptions of various FER methods surveyed in this paper.

Table 1: Literature Review of Various Methods for Face Expression Recognition

Author(s)	Year	Feature Extraction Technique	Classifier	Expression No.	Dataset	Recognition Rate
Mannan et al. [26]	2015	LDN	Multiple SVMs and Decision Level Fusion	7	CK+	96.38%
Natarajan and Muthuswamy[27]	2015	ASM	Action Unit (AU) and Ada-Boost	5	CK+ and FERT	93.6% and 94.4%
Kumar and Garg [28]	2018	gradient Filter, PCA and PSO	Random Forest Classifier	5	JAFFE	93.1%
Hernandez-Matamoros et al. [29]	2015	Gabor Filter and PCA	SVM	-	-	98%
Mliki, Fendri and Hammai[30]	2015	LBP and PCA	SVM	7	JAFFE and CK	96.50% and 99.24%

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Hamester, Barros, and Wermter[31]	2015	-	CNN	7	JAFFE	95.8%
Christou and Kanojiya[32]	2019	-	CNN	7	FER2013	91.12%
Schawn et al. [33]	2017	Dlib-ml	CNN	7	AFEW, FER, and CK	53.2%
Albakoor et al. [34]	2016	Gradient Transformation	BPCC and BPAN	7	FERET and MUG	95%
Kar et al. [20]	2019	ripplet-II transform, PCA and LDA	LS-SVM and RBF	7	CK+ and JAFFE	98.97% and 99.46%
Kar, Babu, and Jena [36]	2017	HOG, PCA, and LDA	BPNN	7	CK+	99.51%
Varma, Shinde, and Shavan[37]	2020	PCA and LDA	HMM and SVM	6	Two unknown datasets	(87.50% and 98.40%) (84.97% and 92.90%)
Rajesh and NaveenKumar [38]	2016	Dlib and PCA	Multi-SVMs	6	CK+, IMM, and own dataset	High Recognition Rate
Das and Chakrabarty[39]	2016	-	SAE+SM	4	CMU	99.68%

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Saurav et al. [40]	2020	ALTP and PCA	K-ELM	7	CK, JAFFE and RFD	99.95%, 95.9% and 97.8%

V. CONCLUSION

This paper provides an overview of research on some efficient methods used in FER system including the techniques of feature extraction and classification. This paper gives a summarized and comparable view on the algorithm utilized by these techniques. Each paper considers a number of facial expressions for recognition such as (happiness, sadness, anger, surprised, fear and disgust). The methods here supposed to gain a high accuracy in the recognition rate. Images are taken from the most widely known databases.

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