Alexandria Engineering Journal (2022) 61, 4307–4321

HOSTED BY

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

An ingenious face recognition system based on HRPSM_CNN under unrestrained environmental condition

M. Tamilselvi *, **S. Karthikeyan**

Dept of ECE, Sathyabama Institute of Science and Technology, Chennai, India

Received 14 June 2021; revised 5 September 2021; accepted 15 September 2021
Available online 24 September 2021

KEYWORD

Face recognition;
LBP;
DBC;
Multi- SVM;
HRPSM_CNN

Abstract Face recognition is an emerging technology that divulges various applications in diverse fields like medical image analysis, surveillance, personal identification, and security related cases. In order to effectively recognize the images from the known data sets, there are a number of face recognition algorithms which are in practice. However, a few problems are encountered in effective recognition with a satisfied parameter. Even though there are various algorithms like Local Binary pattern(LBP), Directional Binary Code(DBC), Multi Support Vector Machine(Multi- SVM), and Convolutional Neural Network(CNN)which are being used for face recognition, still the face recognition is not achieved satisfactorily especially for the large databases as the images are affected due to poor lighting and also owing to occlusion occurring in the stagnant pictures. Hence, a new approach called Hybrid Robust Point Set Matching Convolutional Neural Network (HRPSM_CNN) is proposed to effectively recognize the faces from the data sets over the unconstrained situations. This proposed method shows enhanced receiver operating characteristics when compared to the traditional algorithms. This HRPSM_CNN provides 97 % of accuracy rate for ORL and AR database and 96 % for LFW face database which are significantly higher than the existing traditional algorithms. The proposed algorithm is implemented in visually impaired assistive device and the results show better recognition under difficult situations like various lighting and weather conditions.

1. Introduction

In the last decade, the face recognition has evolved enormously since the automatic recognition system became a necessity for various applications like personal identification, security purposes, biometric applications and generating passcodes, etc. In addition to face, various parameters like fingerprint, eyeball, palm, and ear are taken into account for the process

* Corresponding author.
E-mail addresses: tamilselvivlsi@gmail.com (M. Tamilselvi), skarthi1879@gmail.com (S. Karthikeyan).
Peer review under responsibility of Faculty of Engineering, Alexandria University.

https://doi.org/10.1016/j.aej.2021.09.043

which cannot be accessed easily by all [1].Face recognition is generally used for satisfying two things: validation and recalling. It is very difficult to find the differences between the images since almost all the face images seem to be identical. Very few parameters only will change the structure of the image [2]. In this situation, recognizing the face under some uncontrolled situations like poor lighting conditions, motion pictures, and also the position variation becomes a challenging task, even it has been evolved with many enlightened methods. Hence, it grabs the minds of researchers and stimulates curiosity on finding solutions to the challenges of processing the images under occlusion [3].

There are many algorithms like principal component analysis(PCA), Linear Discriminative Analysis(LDA), Directional Binary Code(DBC) [4] and, Multi Support Vector Machine (Multi SVM) [5] for recognizing the images. In the evolving period of image processing, initially principal component analysis was used for detecting the object and also to reduce the size of the object. This finds the application to be quite effective in recognizing the pattern [6]. But, this technique is suitable for detecting images with specified directions only which cause to lose some part of the image to detect effectively. Hence, the Directional Binary Code (DBC) is used where the features are extracted from the angle of directions [7]. For huge data sets, this technique also encounters a challenging task to recognize. As a result, the new method called Hybrid Robust Point Set Matching Convolutional Neural Network (HRPSM_CNN) is proposed for face recognition. This technique finds the difference from the existing technique where it extracts the features from the image in an effective manner and shows enhanced recognition than the existing traditional methods.

2. Related work

Face Recognition is yet another extremely interesting area of research. This issue turns out to be all the more testing in uncontrolled condition and within the sight of a few varieties like posture, lighting condition and so on which can be done by neighbourhood descriptors [8]. The greater part of the present nearby descriptors consider only the immediate neighbours and not ready to use the more extensive nearby data to make the descriptor progressively discriminative. The more extensive nearby data based descriptors are suffering because of the expanded dimensionality [9]. Here, this issue is comprehended by encoding the relationship over directional neighbourhoods effectively based on the connectivity among the middle picture element and to the nearest neighbourhood picture elements which are used in modelling the new pattern called local directional relation pattern(LDRP).Pattern recognition is used to find a person from continuously moving images [10]. They explained about the recognition of face images automatically under some unexpected situations. Here, the principal component analysis method of image classification is used. They performed this on ORL database and they achieved 90% of recognition rate [11].

Grigorios G, et al. stated the method where the image recognition and tracking are done with making a model that has been unwavering over the basic variations like lighting motion pictures. Here, they implemented a dual way structure on moving low resolute recovered images. In that, primary method is to recover the low range of frequencies and the next method is to recover the higher range of frequencies. These two methods are incorporated by supervised data driven model. Here, the images from $2MF^2$ database are averaged which shows the improvement in results.[12] Fergyanto, et al. explained the concept that the images can easily be processed are taken under the normal and stable conditions. But, the issues arise if the images are taken over the uncontrolled situations like motion or under various lightening conditions. In this paper, singular value decomposition has been used to extract the features from images. To notify that the images are under moving conditions, they are made as low resolution images and then the image has been recognized. Here ORL data set is used where different positions of images for each person are stored and used for training and testing phases. With this concept they achieved improved recognition rate [13].

Instead of recognizing face using Local Binary Pattern (LBP), they used transformation spread function(TFS) based algorithm to manage the face changes under some uncontrolled conditions [14]. K.R.Prabha, et al. discusses the significance of programmed identification of age which finds various applications in security purpose fields. But still this identification becomes a tough task. Hence, they used the Local Binary pattern (LBP) and Grey level co-occurrence matrix to get the nature look of any facial image [15].FaniaMokhayeri explained in her work that face recognition was checked with algorithms like MOBIL (Motion, Blur and Illumination) where the approximation for the face in the gallery was done as convex lambertian surface along with 9D subspace method. They dealt here with position change of the image [16]. Xiaoming Xi, et al. stated that recognizing the veins of finger is another important milestone in the field of biometrics because of having high preservation and comfort. Initially, object connection diagram is worked out to catch relationships among objects. Given the connection diagram, double layouts are changed to depict vein qualities of subjects. Here, the templates which give much more details of the objects are created by maximizing the space among the objects. Finally, the binary frames format is created and trained as a code learner every bit by bit. The data bases used here is PolyU database and MLA database which shows enhanced improvement in performance [17].

Ji-haekim, etal. acquainted a new methodology where numerous mock pictures were developed for each attributing picture which in turn captures the condition of the camera over various lighting conditions. Every attributing image is disintegrated into a number of images which are not concentrated within the region. They are again divided into various in-depth regions to derive the lighting particle. At last, the pictures caught from the in-depth regions are faked based on the original pictures. The proposed technique ensures an intensified recognition method [18]. Significance of privacy in securing the personal information in the form of pictorial representation is shown in this work since life is slowly migrating to pragmatic instruction. A. S. Tolba, etal. together give the information about the awareness of confidential ramification of personal information over the public. This work also proposed a strong individual recognition framework which deals with enormous varieties in posture and garments and can be prepared with hardly any preparation tests. The outputs showed that a bunch of pictures is sufficient to compromise client's protection, even within the sight of confusion [19].

Amrita Parashar explains the significance of machine learning in biometric based uses in an efficient recognition of face with high resolution [20].Here, face detection is done with the Gabor wavelet transform technique and Histogram of Local Binary Pattern (HOLBP) with Dominant Colour Descriptor (DCD). The accuracy rate in this paper is approximately 85% in detecting face using Gabor wavelet transform technique and also this method shows the results in detection with reduced processing time. Midhun Madhusoodanan1 and JiniCheriyan explained the same uncontrolled lighting and continuous moving pictures handled by special kernals which are arbitrarily shaped. The obscured face is displayed as a curved mix of geometrically changed occasions of the engaged exhibition face utilizing TSF method [21]. The test picture is contrasted with the curved mixes in order to locate the best match [10]. To deal with brightening varieties, enlightenment standardization utilizing DWT is utilized for test picture. Steven Lawrence Fernandes and Dr. G. Josemin Bala have discussed various efficient methods for detecting and recognizing the images from continuous moving shots over vague and poor illumination situations. Spherical harmonics and Radial Basis functions (RBF) are used to detect and recognize the images. This method is analysed with Yale B data bases and the results show 98% better recognition rate [22] & [23].

Reena K., etal. insisted the use of scale invariant feature transform (SIFT) for extracting features from the images and provided the better comparison results than the traditional method like Local Binary Pattern(LBP). In addition to that they mentioned the disadvantage of traditional methods where it fails to give an efficient model for these kinds of unconditional problems and they provided the solution for this using SIFT [24]. RanbeerTyagi and Geetam Singh Tomar discussed like most of picture preparing strategies cooperate regarding the impression similar to a two- dimensional sign and applying ordinary sign handling methods to it. Inside this archive, they offer another standard way to deal with the shrouded limitations which are not uncovered by the Sobel and canny channels together in face recognition condition. They also demonstrated the impact of the differentiation and edge around the photographs. In a similar way, they demonstrated methods about the video through which numerous delightful complexity and the concealed information are shared [25].

Mohanraj, et al. introduced a hybrid scale invariant feature transforms(HISFT) along with weighted factor where the stable facial features normalization method is used to comprehend the face recognition issues under lighting and positional changes [26]. They pre-processed the images initially through light adaptation filter mechanism which is used for retina modelling and detected the face by using HOG(Histogram of Oriented Gradients which specifically gives the reduced FP rates. They also used Fast Library for Approximation of Nearest Neighbour (FLANN) for feature matching and to recognize efficiently where they proved that 98% of recognition rate for You Tube celebrity database and 95.5% for extended Yale B database.

3. Proposed method

The main factors that make this face recognition problem quite challenging are image degradation due to blur and appearance variations resulting in illumination and pose. The drawback of the traditional approach is that the challenging problem of blind image deconvolution is required to be solved. Though there have been many attempts in resolving the blind deconvolution problem, it persists. Blur invariant features are extracted from the blurred image and then it is used for recognition which is not efficient. The problem of unconstrained face recognition from remotely acquired images has been addressed. The main factors that make this problem challenging are image degradations due to blur and appearance variations, and illumination and pose. The traditional method of recognition using Local Binary pattern (LBP) does not suit and it is primarily not robust on "flat" image areas since it is based on intensity differences. Within flat image regions, the intensity differences are of small magnitude and highly affected by image noise. Moreover, they are ignorant of the actual intensity level at the location they are computed on. Hence, in the proposed method, it can be seen that both blur and illumination with pose variation are dealt with together. At first, the blur portion alone is considered. It can be resolved with the help of LOG filter. Later the images are detected using Viola Jones algorithm. After completing the aforementioned pose normalization and detection process, the resulting final image undergoes feature extraction and classification. This is performed by the proposed algorithm HRPSM_CNN. Finally, various receiver operating characteristics are analysed for different datasets and the performance is compared with existing algorithms.

The proposed work is explained in the Fig. 1 block diagram. In this, the first step is feeding the images from various data sets like LFW face data set, AR data set and ORL data set for pre-processing. In the next step, the images are pre-processed for further processing where the undesired contortions are removed using LOG filter which is very good at removing noises from the images and also to decrease the contrast of the image by obscuring the corners of the image. The next step constitutes the Viola Jones method of face detection where the human face image is efficiently detected by considering and accounting the pixels present in all directions of the matrix. From this point of block diagram, the images are sent for feature extraction and classification by HRPSM_CNN.

The next step, which is the crux of this paper is that the images are efficiently categorized under various classes in an efficient manner to recognize and identify. Here the proposed algorithm HRPSM_CNN is used and the images are classified by partially taking the features of the images which in turn reduce the time and increase the efficiency of recognizing the image. In the final step, various parameters like accuracy, fmeasure, precision and time are analysed. The following section explains each block of step in more detailed manner.

3.1. Pre-processing

Pre-processing is a well-known process of reducing the external disturbances present in the images and making the image ready for further step of processing without losing the necessary information which are present in the picture. Here Laplacian of Gaussian (LoG) filter is used to face the irregular noise sensitivity related problems of normal Laplacian filter. In order to improve the efficiency, the low resolute images of Gaussian type are generated and imposed on the image as smoothening process which in turn helps to pull out the noise. Once this

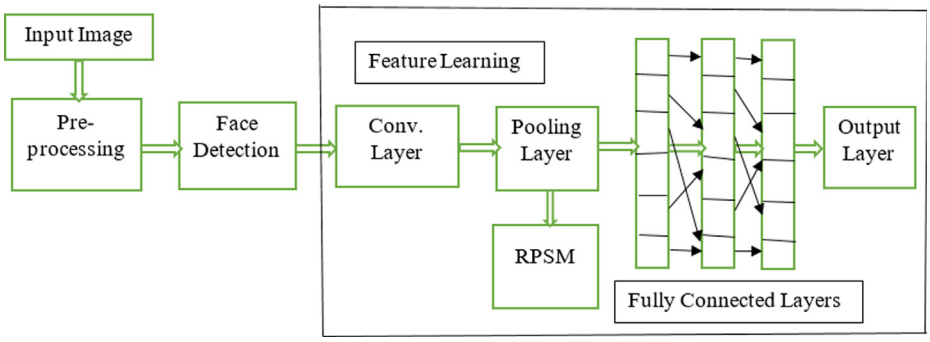

Fig. 1 Block diagram of the Proposed Method.

method is applied, then the change in the sign values represent the edges which also insist that the prime key points are lying at the nearby edges as a result the intensity values get changed furiously. Owing to similarities among one another, sometimes they will occur where the places which are not located easily. Log filter will detect the lines. The image pixel intensity in terms of Laplacian is given by

$$\boldsymbol{L}(\boldsymbol{x},\boldsymbol{y}) = \frac{\partial \boldsymbol{I}^2}{\partial \boldsymbol{x}^2} + \frac{\partial \boldsymbol{I}^2}{\partial \boldsymbol{y}^2} \tag{1}$$

Decreasing the undesirable disturbances before sending it to the differentiation operation is a significant step. The equation given below is the standard deviation of Gaussian as

$$\log(\boldsymbol{x},\boldsymbol{y}) = \frac{-1}{\boldsymbol{\pi\sigma}4} * \left(1 - \frac{\boldsymbol{x}^2}{\boldsymbol{y}^2} * \boldsymbol{exp}\left(-\frac{\boldsymbol{x}^2}{2\boldsymbol{\sigma}2}\right)\right) \tag{2}$$

In order to achieve the required output, it is necessary to convolute the Gaussian smoothening filter and the Laplacian filter. Individual face image of size m × n is mentioned as M set of images which are under test. Concatenate every row or else every column as a single dimensional vector to represent two dimensional images. S matrix structure is formulated by $S = [x_1, x_2, x_3 \ldots\ldots x_M]$. Here $xi = [p_1,p_2,p_3 \ldots\ldots\ldots\ldots p_{mn}]$. Subtract the mean image from image vector and hence similar details are pulled out. Mean of the image is represented as m and is given by

$$m = \frac{1}{M}\sum_{i=1} Mxi \tag{3}$$

where x_i is the mean of the centred image

$$x'_i = x_i - m \tag{4}$$

For this mean of centred image, 5 × 5 size of matrix structure like Laplacian of Gaussian filter is applied and then subtraction is implemented over centred mean image in order to fetch the significant distinction of faces. Table 1 describes an example of LoG filter matrix and Fig. 2 shows the input given to the LoG filter and the output after applying LoG filter.

3.2. Face detection

In computer vision applications, detecting human face from the given images are playing a significant role. Face detection is difficult under the situation like position change, texture of skin, illumination condition, wearing of extra goggles and the quality of camera used. The vital role of the face detection algorithm is to identify the face in the given frame of picture.

In practise, there are many number of algorithms which are available for face detection. Among this, Viola Jones algorithm is used. The Viola Jones algorithm extracts features by Harr like structure and then these are classified by cascade classifier along with Ada Boost algorithm. Here, initially, the particular region is computed by Harr features which are then applied to cascade of Ada Boost classifiers. The region of interest is set as W × H size for scanning and then features are extracted and classified as edge features and center surround features. Harr features are computed as per region of interest as weighted sum of pixels in the shaded rectangles of the feature. It is represented as

$$feature = \sum_{ie[1,2]} \omega_i RecSum(r_i) \tag{5}$$

where r_i is the shaded rectangle of size (w < W, h < H) in the feature, w_i is the weight associated with that shade and J {1,2,3... 14} refers to a particular 'Harr' feature. Number of features extracted depends upon the object which is going to be detected where a minimum part of the features among maximum feature pool is used.

Fig. 3 shows a output of face detection. The selection of the features is done by the classifier cascade where it is trained using the Discrete Ada boost algorithm. For recognizing different objects, different cascades are available and in this system, both the frontal face and profile face cascades are used.

Table 1 The LoG filter matrix.

The Log filter matrix				
0444	0.0464	0.0560	0.0464	0.0444
0.0464	0.3163	0.7142	0.3163	0.0464
0.0560	0.7142	−4.9044	0.7142	0.0560
0.0464	0.3163	0.7142	0.3163	0.0464
0.0444	0.0464	0.0560	0.0464	0.0444

Fig. 2 a) Input image to the Log filter b) Input Image-Image after applying LoG filter.

Fig. 3 Face Detection Output.

The face cascades are already trained in such a way that when an image portion (windowed region) is passed through it, suitable features which can discriminate facial patterns from non-facial patterns are computed successively through each classifier stage.

3.3. Feature extraction and face recognition

The novel algorithm HRPSM_CNN is used to recognize faces under some unpredicted and unusual situations. Since the person images are obstructed over various conditions like poor lighting, position change and also during continuous motion. There are many methods to recognize images during these situations. But this novel algorithm implements robust point set matching where partial features are extracted from the images and then compared with the original gallery images to recognize and then this algorithm uses CNN to extract features and to classify them according to the appropriate category for efficient face recognition.

Robust point set matching algorithm finds its importance when a couple of gallery images and a test face fix were given. This algorithm primarily recognizes the key points and also their neighbourhood textural highlights. This RPSM algorithm matches those evoked key points, and this information is used for continuous finding and matching of the images. At last, the closeness of two images are changed like the separation over two adjusted key point sets.

This algorithm mainly imparts key points set matching for partially recognizing the faces. This RPSM algorithm is able to be in line with the semi recognized image and also with actual images present in the gallery which has the impact of various effects like bad lighting, poor positions, and different expressions of persons. Soon after it is getting in line with the compared image, it can recognize the faces by the unique

property of matching robustly by finding the distance between the derived set points.

Robust point set matching along with CNN is used for effectively enhancing the face recognition accuracy even there are many traditional methods and algorithms which are existing. Robust point set matching algorithm is based on finding the similarities between gallery images and probe images by concentrating on the key features and also by finding the distance between two points where the similarities are found. This finds its application in partial face recognition under various unexpected situations. Convolutional neural network (CNN) finds its effective application in recognizing faces by extracting the features from images and classifying them according to their category and also processing them through different layers by the means of linear sequencing operation which is known as convolution. It has many concealed layers along with input and output layers. Here the HRPSM_CNN algorithm consists of layers like convolutional, max. pooling, fully connected and softmax layers.

The following steps are involved in HRPSM_CNN algorithm.

Step 1: The images from various data sets like LFW face data set, AR data set and ORL data set are given

as input

Step 2: The images are segmented into various groups according to the similarities existing among them.

Then the data are categorized and separated for training and testing.

Step 3: HRPS_CNN is started to establish. The inputs are given to convolutional layer in the form of

N * X * Y * H where

N ---- Number of images

X ---- width of image

Y ---- Height of image

H ---- Depth of image

Here the features from images are extracted and formed as activation maps which give the details of the images to the next layer as input.

Step 4: This is the significant part where the key points set matching is applied in pooling layer. Pooling layer separates the received images from previous layer. This divides the image as a group which contains only non inter weaving regions. Instinctively, the specific area of a component is less significant than its unpleasant area when compared to different highlights. This is the thought behind the utilization of pooling in convolutional neural systems. The pooling layer serves to dynamically lesser the spatial size of the portrayal, to decrease the quantity of parameters and its utilization space and also speed. This layer works freely over each deepness of the information and decrease the size geographically. General form of pooling layer for the filter size 2 X 2 in order to avoid the activation is

$$F_{x,y}(s) = S_{2x+a12y+b} \tag{6}$$

Step 5: RPSM is applied to the output of pooling layer where the key features are matched and identified. RPSM reduces the number of key feature to recognize the faces which in turn increase the recognition rate and accuracy.

```
HRPS_CNN Algorithm for Face recognition
Initialized input data (X1,X2,X3. . . . . .Xn)
Segment X →Region
Set point→ X (R (:))
Train the data train → (Xt)
Test data test → (Xn)
Apply RPSM_CNN
t * learn.layer.conv_2d
t * learn.layer.max_pool_2d
t * learn.layer.fullyconnected_2d
t * learn.layer.softmax
model → predict.model(X)
X(k) = (X1(k) + X2(k) + . . . . . + XK(k)) – Independent
variable
Wjk → (W1jk , W2jk, . . . . . Wnjk)
For 1 : 2 : num (net.layer)
For 1 :nume (net.layers({1-a},a)
Temp = temp + Wij + X (j)
end
end
```

The above pseudocode explains the steps followed in the HRPS_CNN algorithm layer by layer and the Fig. 4 shows the output of pre-processed image, partial key points extraction and the processed image through HRPSM_CNN.

Step 6: This layer is fully connected layer which connects neurons or information from all other layers or activation maps. In this layer only the matrix structure is converted into vector and it creates a model with the retrieved information

(a) (b) (c)

Fig. 4 (a) Pre-processed image (b) Partial key points extraction (c) Processed image through HRPSM_CNN.

Fig. 5 (a) Pre-processed image (b) HRPSM_CNN classified image.

Fig. 6 (a) Input Image (b) HRPSM_CNN recognized output image.

from the previous layers. The output from this fully connected layer is given to softmax layer.

Step 7: After receiving the inputs from the fully connected layers, it is classifying the images according to the similarities present among them and sending the output to the output layer. Fig. 5 shows the pre-processed image and HRPSM_CNN classified image.

Step 8: The output layer outputs the recognized face from the given data sets in an efficient manner.

Table 2 Parametric analysis for Different Algorithms applied over various databases.

Data set	Algorithm	Accuracy	Precision	Recall	fmeasure	Time(ms)
ORL	DBC	88.5	89	90	92	3.8
	CNN	94	92	92	96	3.1
	HRPSM_CNN	97	94	96	97	2.5
AR	DBC	89	90	89	91	3.5
	CNN	95	93	94	93	2.8
	HRPSM_CNN	97	94	93	95	2.5
LFW	DBC	89	90	88	90	3.6
	CNN	94	92	93	95	2.7
	HRPSM_CNN	96	93	94	95	2.4

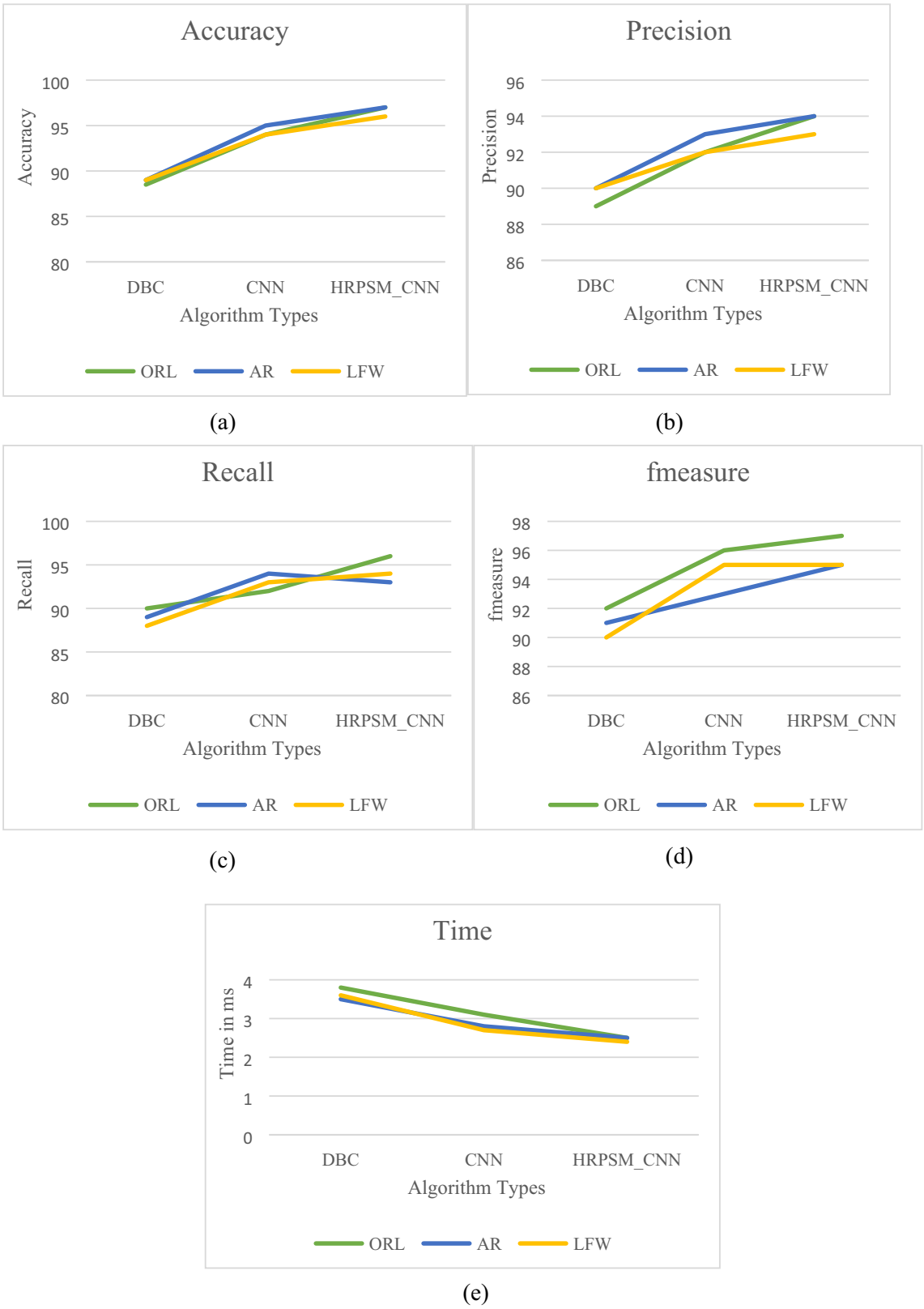

Fig. 7 Comparison graph of parametric analysis (a) Accuracy values for ORL, AR and LFW face data for DBC, CNN, HRPSM_CNN (b) Precision values for ORL, AR and LFW face data for DBC, CNN, HRPSM_CNN (c) Recall values for ORL, AR and LFW face data for DBC, CNN, HRPSM_CNN (d) fmeasure values for ORL, AR and LFW face data for DBC, CNN, HRPSM_CNN (e) Time values for ORL, AR and LFW face data for DBC, CNN, HRPSM_CNN. X Axis : DBC Vs CNN Vs HRPSM_CNN and Y Axis: Accuracy, Precision, Recall, fmeasure& Time.

Step 9: Finally based on the efficient classification the receiver operator characteristics are measured. Fig. 6 illustrates the recognized output image along with the input image.

4. Experiment and discussion

In this section, the detailed parametric analysis was done in order to justify the efficiency of the proposed algorithm. The supremacy of the proposed algorithm has been showcased by comparing various parameters for different data sets like ORL, AR, and LFW face. Data sets chosen for demonstration were described in detail in the following sub sections. The identified outputs of parametric analysis for parameters like accuracy, precision, recall, fmeasure and recognition time was shown and explained in the following section.

4.1. Datasets

1. ORL data set

This data set contains 400 images with each image size of 112 × 92. Here 40 persons, for each individual 10 images are there. They were taken over various conditions like times, illumination and with different expressions.

Table 3 Statistical analysis obtained for ORL Dataset images.

Parameter	Group	N	Mean	Std. Deviation	Std. Error Mean
Accuracy	DBC	10	84.3980	2.85666	0.90335
	CNN	10	92.1050	1.17342	0.37107
	HRPSM_CNN	10	95.4500	1.2211	0.38615
Precision	DBC	10	85.6690	2.61382	0.82656
	CNN	10	89.2500	1.81322	0.57339
	HRPSM_CNN	10	91.6250	1.77095	0.56002
Recall	DBC	10	87.7000	1.26425	0.39979
	CNN	10	89.2150	1.91559	0.60576
	HRPSM_CNN	10	92.7810	2.38622	0.75459
fmeasure	DBC	10	89.6000	1.91761	0.60640
	CNN	10	92.8390	2.36293	0.74722
	HRPSM_CNN	10	94.3947	1.56320	0.49433

Table 4 Comparison of significance level in ORL dataset samples.

Parameter	Group	One-Way ANOVA test				
		Sum of squares	df	Mean square	F	Significance level
Accuracy	Between groups	642.445	2	321.223	87.380	
	Within groups	99.257	27	3.676		
	Total	741.702	29			
Precision	Between groups	179.794	2	89.897	20.345	< 0.001
	Within groups	119.305	27	4.419		
	Total	299.098	29			
Recall	Between groups	136.094	2	68.047	18.623	< 0.001
	Within groups	98.657	27	3.654		
	Total	234.751	29			
fmeasure	Between groups	135.317	2	67.658	17.342	< 0.001
	Within groups	105.338	27	3.901		
	Total	240.655	29			

Table 5 Statistical analysis obtained for AR Dataset images.

Parameter	Group	N	Mean	Std. Deviation	Std. Error Mean
Accuracy	DBC	10	85.8340	2.68486	0.84903
	CNN	10	92.5020	1.54428	0.48834
	HRPSM_CNN	10	93.7300	2.19193	0.69315
Precision	DBC	10	87.6950	1.37021	0.43330
	CNN	10	90.5750	1.85985	0.58813
	HRPSM_CNN	10	91.5760	1.61441	0.51052
Recall	DBC	10	85.7400	2.56242	0.81031
	CNN	10	91.3750	1.50651	0.47640
	HRPSM_CNN	10	99.5800	2.02295	0.63971
fmeasure	DBC	10	87.7730	1.82575	0.57735
	CNN	10	90.7400	1.30422	0.41243
	HRPSM_CNN	10	90.3327	1.48119	0.46839

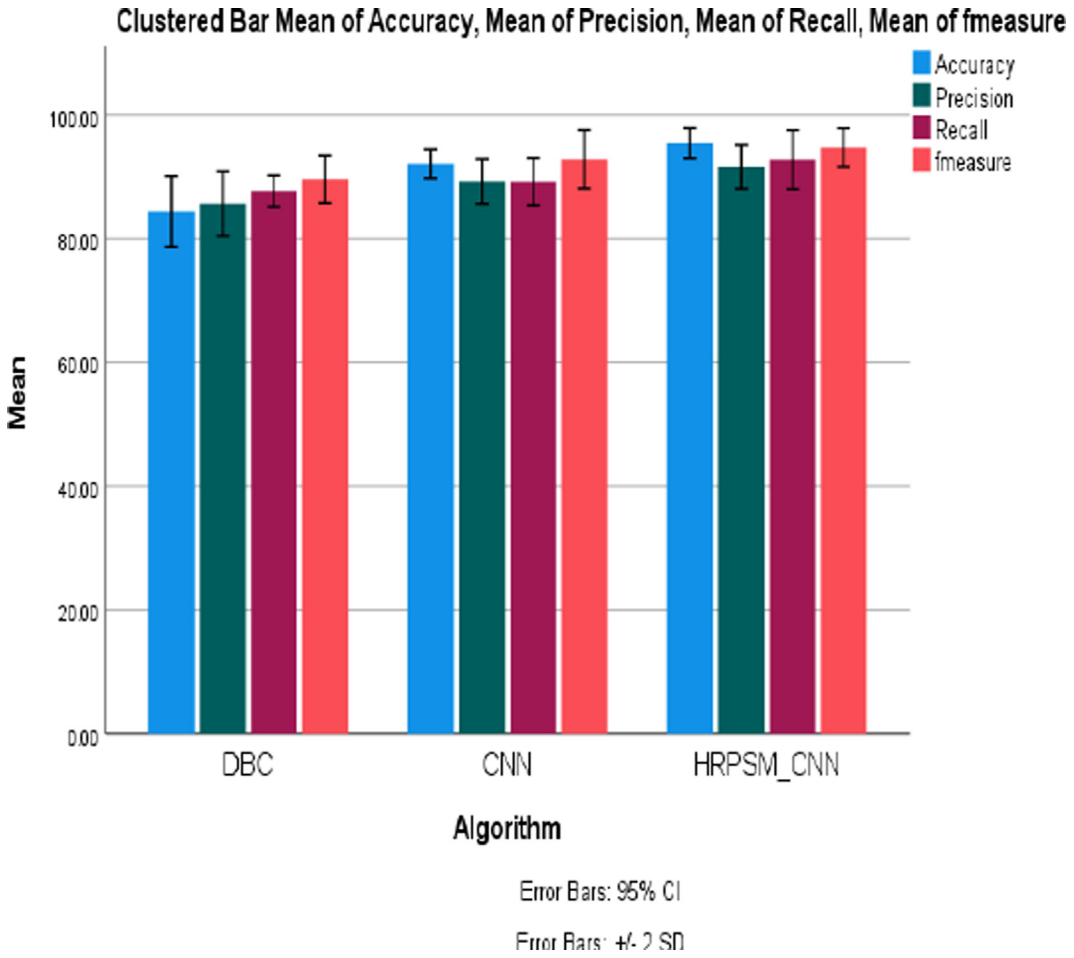

Fig. 8 Graphical representation of comparative analysis in ORL Dataset.

2. AR data set

This data set includes more than 4000 images of 126 individuals among this 70 are derived from men and 56 are from women. This data set also contains various images taken over different conditions like poor lighting, under the occluded situations and also with various face expressions. The pictures of each individual are taken with two different sessions in order to catch all the possibilities of conditions.

3. LFW Face data set

Nearly 13,000 images were collected from web sources and stored in this data set. The data set contains the pictures along with their names and 1680 pictures of them are repeated two or three times with slight variations in capturing photos.

4.2. Parametric analysis

In this section, the various parameters of the graphs are shown for different data sets. The parameters which are taken into account for analysis are Accuracy, Precision, Recall, fmeasure, and Time. Each parameter is analysed for the algorithms like Directional Binary Code (DBC) along with Multi SVM for face recognition, CNN based face recognition and Hybrid Robust Point Set Matching Convolutional Neural Network (HRPM_CNN) based face recognition.

1. Accuracy – It is the parameter which gives the ratio of efficient recognition of faces from the data sets. In another way it also gives the value of estimated monitoring over the total monitoring. Indirectly it indicates that more or less the values should be the same for false negatives and false positives.

$$Accuracy = (TP + TN)/(TP + TN + FP + FN) \tag{7}$$

2. Precision – This parameter gives the details of rightly observed values over the total positive predicted values.

$$Precision = TP/(TP + FP) \tag{8}$$

3. Recall – This parameter clearly gives the measure of how much it has been reproduced over the positive predictions.

$$Recall = TP/(TP + FN) \tag{9}$$

4. F measure – This is an accuracy measure which can also be known as the weighted harmonic mean of precision and recall

$$Fmeasure = 2X((PrecisionxRecall)/(Precision + Recall)) \quad (10)$$

5. Time – It gives the measure of time, how much it has taken for the recognition of face over the number of images in the huge data set.

The Table 2 shows the quantified value of the parameters for various data sets for different algorithms like Directional Binary Code (DBC) along with Multi SVM for face recognition, CNN based face recognition and Hybrid Robust Point Set Matching Convolutional Neural Network (HRPSM_CNN) based face recognition. The proposed algorithm HRPS_CNN shows the enhanced performance over all the parameters comparing to the other two algorithms. It recognizes the face in a less time compared to the other algorithms. Here the novelty of the proposed algorithm is practically shown and verified.

The following figure shows the comparison of the above mentioned parameters for different data sets like ORL, AR and LFW face data set. Fig. 7 illustrates the comparison of various parametric analysis for different algorithms such as DBC, CNN, HRPSM_CNN

4.3. Statistical analysis and discussion

In the previous section, the parametric analysis is carried out for various parameters to show the enhancement in the proposed algorithm. In addition to the proposed method, the work was statistically analyzed by using IBM Statistical Package for Social Sciences (SPSS). The mean, standard deviation, and standard error mean were calculated. This SPSS analysis was carried out for three different data bases with sample size. The analysis was carried out by comparing the DBC, CNN and HRPSM_CNN algorithms for various ROC characteristics such as Accuracy, Precision, Recall and fmeasure. To perform this statistical analysis, a sample size of 10 images are taken from each database such as ORL, AR &LFW face. In SPSS analysis, input images that are taken from the data base are considered as an Independent variable and the parameters such as accuracy, precision, recall, and fmeasure that are required to measure are considered as a dependent variable. Based on these two variables, the descriptive analysis was performed by One-Way Anova test. As a result of this SPSS analysis, a significant variation was observed among the ROC characteristics for various algorithms. (Tables 3, 4 and 5). Bar charts show the comparison of mean values along with error bars as shown in (Figs. 8, 9, and 10) for ORL, AR and LFW face database respectively. The results and analyses show that the proposed HRPSM_CNN suits more for better face recognition under uncontrolled environment.

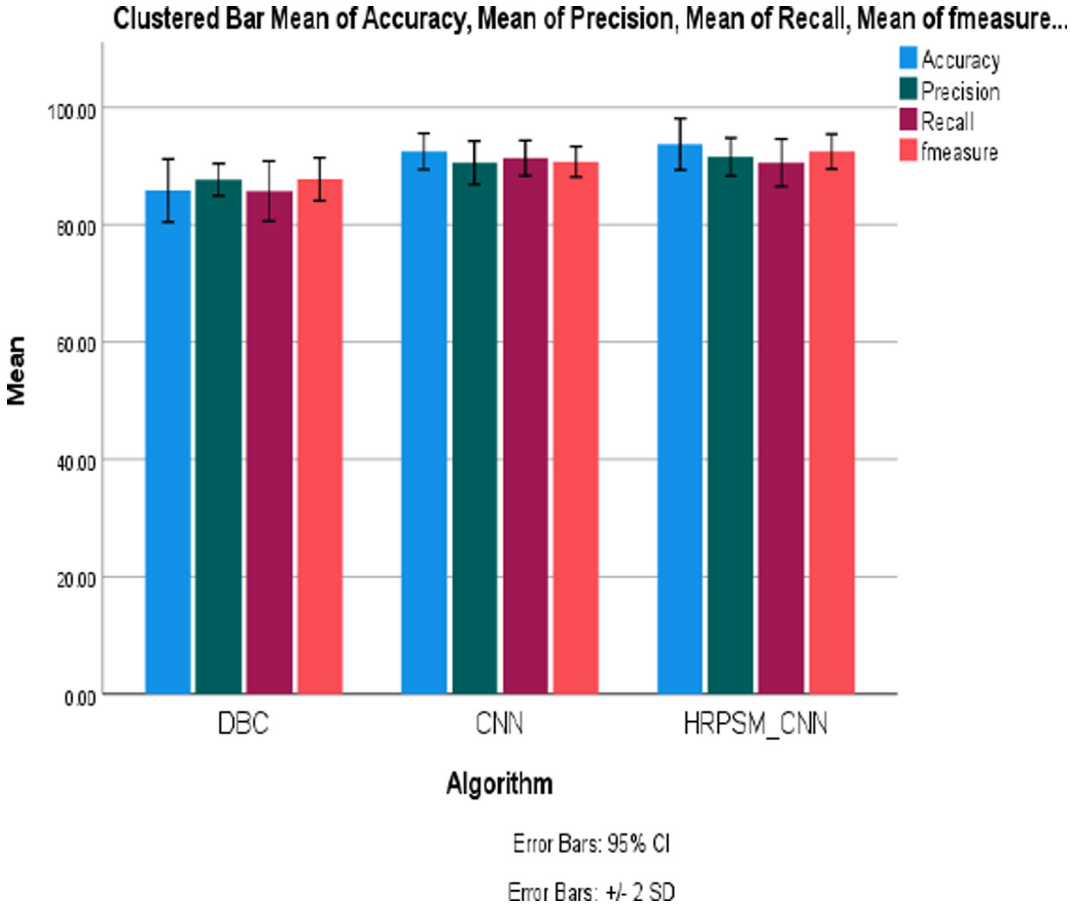

Fig. 9 Graphical representation of comparative analysis in AR Dataset.

Table 3 shows the statistical Analysis of Mean and Standard Deviation for DBC, CNN & HRPSM_CNN algorithms for ORL database. There is a significant difference between the algorithms in accuracy, precision, recall, and fmeasure. HRPSM_CNN has higher accuracy (95.45), precision (91.62), recall(92.78) & fmeasure(94.39).Table 4 shows the comparison of Significance Level with value $p < 0.05$. The algorithms DBS, CNN and HRPSM_CNN for ORL database have a confidence interval of 95% and the significance levels of accuracy, precision, recall, and fmeasure are < 0.05. Fig. 8: Comparison analysis of mean of accuracy, precision, recall, and fmeasure for three groups of algorithms DBC, CNN & HRPSM_CNN in ORL Dataset. The mean accuracy, precision, recall, and fmeasure of HRPSM_CNN shows better results compared to the DBC and CNN with error bars 95% CI, parameters show statistically significant ($p < 0.05$) and it

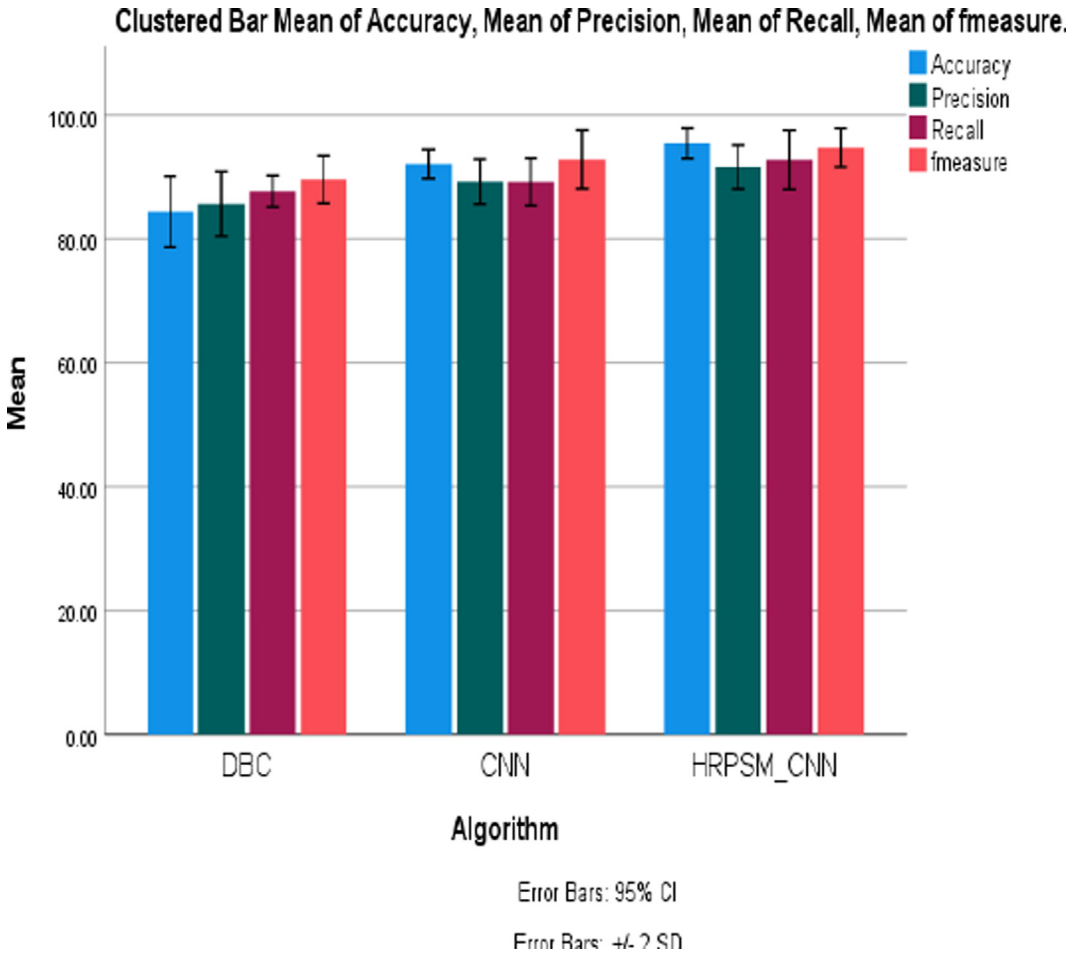

Fig. 10 Graphical representation of comparative analysis in LFW Dataset.

Table 6 Comparison of significance level in AR dataset samples.

Parameter	Group	One-Way ANOVA test				
		Sum of squares	df	Mean square	F	Significance level
Accuracy	Between groups	361.057	2	180.528	37.616	< 0.001
	Within groups	129.580	27	4.799		
	Total	490.637	29			
Precision	Between groups	81.195	2	40.598	15.334	< 0.001
	Within groups	71.485	27	2.648		
	Total	152.681	29			
Recall	Between groups	186.036	2	93.018	21.585	< 0.001
	Within groups	116.351	27	4.309		
	Total	302.387	29			
fmeasure	Between groups	113.504	2	56.752	23.554	< 0.001
	Within groups	65.054	27	2.409		
	Total	178.558	29			

Table 7 Statistical analysis obtained for LFW Dataset images.

Parameter	Group	N	Mean	Std. Deviation	Std. Error Mean
Accuracy	DBC	10	85.6750	2.70500	0.85540
	CNN	10	90.8660	2.06812	0.65400
	HRPSM_CNN	10	92.9340	2.33890	0.73962
Precision	DBC	10	88.1050	1.12409	0.35547
	CNN	10	89.7300	1.75961	0.55644
	HRPSM_CNN	10	90.8140	1.97447	0.62438
Recall	DBC	10	86.6900	0.84650	0.26769
	CNN	10	90.0840	1.92761	0.60956
	HRPSM_CNN	10	90.8980	2.03858	0.64466
fmeasure	DBC	10	87.9520	1.37564	0.43501
	CNN	10	92.8590	1.57093	0.49677
	HRPSM_CNN	10	92.6910	1.54400	0.48825

Table 8 Comparison of significance level in LFW dataset samples.

Parameter	Group	One-Way ANOVA test				
		Sum of squares	df	Mean square	F	Significance level
Accuracy	Between groups	279.721	2	139.860	24.588	< 0.001
	Within groups	153.582	27	5.688		
	Total	433.302	29			
Precision	Between groups	37.181	2	18.591	6.753	0.004
	Within groups	74.325	27	2.753		
	Total	111.506	29			
Recall	Between groups	99.630	2	49.815	17.402	< 0.001
	Within groups	77.292	27	2.863		
	Total	176.923	29			
fmeasure	Between groups	155.217	2	77.608	34.523	< 0.001
	Within groups	60.697	27	2.248		
	Total	215.914	29			

shows the effective prediction. X Axis: DBC Vs CNN Vs HRPSM_CNN and Y Axis: Mean Accuracy, Precision, Recall,& fmeasure of detection +/- 2 SD

Table 5shows the statistical Analysis of Mean and Standard Deviation for DBC, CNN & HRPSM_CNN algorithms for AR database. There is a significant difference between the algorithms in accuracy, precision, recall, and fmeasure. HRPSM_CNN has higher accuracy (93.73), precision (91.57), recall(99.58) & fmeasure(90.33).Table 6shows the comparison of Significance Level with value $p < 0.05$. The algorithms DBS, CNN and HRPSM_CNN for AR database have a confidence interval of 95% and the significance levels of Accuracy, precision, recall, and fmeasure are < 0.05. Fig. 9 represents the comparison analysis of mean of accuracy, precision, recall, and fmeasure for three groups of algorithms namely DBC, CNN & HRPSM_CNN in AR Dataset. The mean accuracy, precision, recall, and fmeasure of HRPSM_CNN show better results compared to the DBC and CNN with error bars 95% CI, parameters show statistically significant ($p < 0.05$) and it shows the effective prediction. X Axis: DBC Vs CNN Vs HRPSM_CNN and Y Axis: Mean Accuracy, Precision, Recall,& fmeasure of detection +/- 2 SD

Table 7 represents the statistical Analysis of Mean and Standard Deviation for DBC, CNN & HRPSM_CNN algorithms for LFW face database. There is a significant difference between the algorithms in accuracy, precision, recall, and fmeasure. HRPSM_CNN has higher accuracy (92.93), precision (90.81), recall(90.89) &fmeasure(92.69). Table 8 shows the comparison of Significance Level with value $p < 0.05$. The algorithms DBS, CNN and HRPSM_CNN for LFW face database have a confidence interval of 95 % and the significance levels of Accuracy, precision, recall, and fmeasure are < 0.05. Fig. 10 represents the Comparison analysis of mean of accuracy, precision, recall, and fmeasure for three groups of algorithms DBC, CNN & HRPSM_CNN in LFW Dataset. The mean accuracy, precision, recall, and fmeasure of HRPSM_CNN show better results compared to the DBC and CNN with error bars 95% CI, parameters show statistically significant ($p = 0.020$) and it shows the effective prediction. X Axis: DBC Vs CNN Vs HRPSM_CNN and Y Axis: Mean Accuracy, Precision, Recall,& fmeasure of detection +/- 2 SD

5. Application in healthcare systems

The face recognition system finds application in many fields that includes in finding the assistive devices for the visually challenged persons to help them in recognizing the person near to them that enables them to effectively interact with the persons in the public places with more confidence like normal persons. There are many such devices which are already available in practice that works well over the normal conditions by recognizing the faces and then the person name is converted from text to audio that makes the visually challenged person to

know about the person standing next to them. But this system fails when the situations are uncontrolled. Hence, this has resulted in the development of a better model to help the visually challenged persons within a closed loop over a specific distance to recognize the persons surrounding them even under the unconfined environment situations. This method accepts the input as image and the final output will be an audio to a visually challenged person. First the images are captured as video stream and the picture frames are taken from that as input. Then the face is detected from the selected picture frame and finally by applying the proposed algorithm HRPSM_CNN, the feature extraction and classification is done and there by the face is recognized. The recognized face is identified with the name by comparing with the reference data available. Then the name is given in the form of text to audio conversion module that is connected to visually challenged person which makes him to identify the person standing nearby. The proposed work, shows enhanced accuracy rate as 98% for face detection and 95% for face recognition that is significantly better than the existing methods. In this work, the analysis is done with the minimum data set with certain distance to ensure the recognition in an accurate manner. In future, this can be extended to large data set with reasonable distance that enables the visually challenged person to effectively recognize the persons and to interact with them in common places.

6. Conclusion

This paper proposed an efficient method for an effective face recognition under some unmanaged situations. The basic idea of this proposed work is to recognize the image even with the different situations like pose variation, poor lighting and also in moving. In this work, images are pre-processed and then faces are detected by Viola Jones algorithm and finally features are extracted and classified by the proposed algorithm HRPSM_CNN. As the step by step process of images through different layers in hybrid RPSM_CNN, the images are recognized over region of interest. In the pooling layer of RPSM_CNN, key points are extracted and matched which helps in recognizing the partially faced images which also help to classify them. This process in turn reduces the time required for recognition. The proposed algorithm is able to recognize the faces in an efficient manner and finally their parameters are analysed and the same is compared for various data sets like ORL, AR and LFW face data set. With this proposed algorithm of HRPSM_CNN, accuracy rate of 97% which is 1.3% better than the other algorithms is achieved. The data sets ORL, AR and LFW face are analysed with various parameters where all the parameters taken were maintaining or enhancing the face recognition performance in a significant manner. Also the proposed algorithm is applied in visually impaired assistive system, and the results shows better recognition of 95% under difficult situation like various lighting and weather conditions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Guru Kumar Lokku, G. Harinatha Reddy, M. N. Giri Prasad, "Automatic Face Recognition for Various Expressions and Facial Details. Int. J. Innovative Technol. Exploring Engineering (IJITEE). ISSN: 2278-3075, 8(9S3), July 2019.

[2] S.R. Dubey, Local Directional Relation Pattern for Unconstrained and Robust Face Retrieval", This paper is published in Multimedia Tools and Applications, Springer. Cite this article as: S.R. Dubey, "Local Directional Relation Pattern for Unconstrained and Robust Face Retrieval", Multimedia Tools and Applications 78 (19) (2019) 28063–28088, https://doi.org/10.1007/s11042-019-07908-3.

[3] R. Govindaraj, E. Logashanmugam, Multimodal verge for scale and pose variant real time face tracking and recognition, Indonesian J. Electrical Eng. Computer Sci. 13 (2) (2019) 665.

[4] M.Tamilselvi, S.Karthikeyan. A Face Recognition System using Directional Binary Code Algorithm and Multi-SVM. Int. J. Eng. ad Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-8, Issue-6S3, September 2019

[5] Amrutha S Nair1 Smita C Thomas, Non–Uniform Motion on Blur, Illumination, and Pose in Face Recognition", IJSRD – Int. J. Scientific Research Development. 3(09), 2015 | ISSN (online): 2321-0613.

[6] FaniaMokhayeri† , Eric Granger†, Guillaume-Alexandre Bilodeau," synthetic face generation under various operational conditions in video surveillance, in: IEEE International Conference on Image Processing (ICIP), 2015

[7] P. VenkateswarLal, G.R. Nitta, A. Prasad, Ensemble of texture and shape descriptors using support vector machine classification for face recognition, J. Ambient Intell. Human Comput. (2019), https://doi.org/10.1007/s12652-019-01192-7.

[8] M. Tamilselvi, S. Karthikeyan, Feature Extraction and Facial Expression Recognition using Support Vector Machine, in: 2019 International Conference on Smart Systems and Inventive Technology (ICSSIT), Tirunelveli, India, 2019, pp. 889-893.

[9] V.Abirami ,V.Jothilakshmi, Face Recognition Across Non-Uniform Motion Blur, Illumination and Pose, in: International Research Journal In Advanced Engineering And Technology (IRJAET)", ISSN (PRINT) : 2454-4744 ISSN (ONLINE): 2454-4752. 1(4), 378 - 382, December, 2015.

[10] M.A. Jiayi et.al, Robust Point Matching via Vector Field Consensus. IEEE Trans. Image process., 23(4), 2014

[11] G. Ramkumar, E. Logashanmugam, An effectual face tracking based on transformed algorithm using composite mask, in: IEEE International Conference on Computational Intelligence and Computing Research (ICCIC), 2016, pp. 1–5.

[12] G. Grigorios. Chrysos1 ·Paolo Favaro2·Stefanos Zafeiriou1, "Motion Deblurring of Faces. Int. J. Computer Vis. 10.1007/s11263-018-1138-7

[13] Fergyanto E Gunawan, JeklinHarefa, NobumasaSekishita, Face Recognition on Linear Motion-blurred Image, in: TELKOMNIKA", Vol.16, No.3, June 2018, pp. 1249∼1255 ISSN: 1693-6930, accredited A by DIKTI, Decree No: 58/DIKTI/Kep/2013 DOI: 10.12928/TELKOMNIKA.v16i3.5480.

[14] Ramkumar G, Logashanmugam E, Study on impulsive assessment of chronic pain correlated expressions in facial images. Biomed. Res. 29 (16): 3181-3187. ISSN 0970-938X, 2018

[15] K.R. Prabha, B. Chitra, M. Gowsalya, T. Janani, Human Age Recognition from Facial Images in Image Processing using MATLAB, J. Sig. Processing Wireless Netw. 3 (1) (2018) 17–20.

[16] M. Tamilselvi, G. Ramkumar, (2015). Non-invasive tracking and monitoring glucose content using near infrared spectroscopy, in: IEEE International Conference on Computational Intelligence and Computing Research (ICCIC), Madurai, 2015, pp. 1-3

[17] Xiaoming Xi, Lu Yang, Yilong Yin, Learning discriminative binary codes for finger vein recognition, Pattern Recogn. 66 (2017) 26–33.

[18] X. Li, P. Hao, L. He, et al, Image gradient orientations embedded structural error coding for face recognition with occlusion, J. Ambient Intell. Hum. Comput. (2019), https://doi.org/10.1007/s12652-019-01257-7.

[19] M. Tamilselvi, G. Ramkumar, An effectual contrast enhancement for remote sensing images, Int. J. Appl. Eng. Res. 10 (20) (2015).

[20] Amrita Parashar, "Face Detection Using Gabor Wavelet Transform with Histogram of Local Binary Pattern with Dominant Color Descriptor", Int. J. Eng. Res. Technol. (IJERT). ISSN: 2278-0181, 6(04), April-2017, http:// www.ijert.org

[21] M. Tamilselvi, S. Karthikeyan, G. Ramkumar, Face Recognition based on Spatio Angular Using Visual Geometric Group-19 Convolutional Neural Network, Ann. Romanian Soc. Cell Biol. (2021) 2131–2138.

[22] Steven Lawrence Fernandes, Dr. G. JoseminBala, A Novel Technique to Detect and Recognize Faces in Multi-view Videos, in: Recent Advances in Computer Science. ISBN: 978-1-61804-320-7

[23] J. Wu, X. Sun, Z. Wang, Shearlet feature manifold for face recognition, J. Ambient Intell. Hum. Comput. 10 (2019) 3453–3460, https://doi.org/10.1007/s12652-018-1063-1.

[24] ReenaK.A1, Jithu V.S, Face Recognition across Non-Uniform Motion Blur Using Efficient Feature Extraction Algorithm, in: International Journal of Engineering Science and Computing, September 2016, Volume 6 Issue No. 9.

[25] Ranbeer Tyagi, Geetam Singh Tomar, Unfamiliar Sides, Video, Image Enhancement in Face Recognition, Int. J. Hybrid Information Technol. 9 (11) (2016) 255–266, https://doi.org/10.14257/ijhit.2016.9.11.22.

[26] V. Mohanraj, M. Vimalkumar, M. Mithila, V. Vaidehi, 6–8 September 2016, Cochin, India indexed in Science Direct, Procedia Comput. Sci. 93 (2016) 503–512.