Chapter 11
An Optimal Hybrid Solution to Local and Global Facial Recognition Through Machine Learning

K. Raju, B. Chinna Rao, K. Saikumar, and Nalajala Lakshman Pratap

Abstract Face recognition need is fine assured as enormous industrial relevance use them to implement one or another objective. As the programmes move closer to everyday usage to hold a database of actual events, an individual's identification primarily demanded as an instance of consistency. As facial recognition has beating advantages over other industrial applications and human eyes can quickly evaluate performance, improved algorithms and smaller computing costs are continuously improving this methodology. This research takes the conventional algorithms of recognition in the first stage and uses hybrid approaches to counter their limitations. The study starts with basic computation of global face features using Principal Component Analysis (PCA), Discrete Wavelet Transform (DWT) and Independent Component Analysis (ICA), with some standard classifiers like Neural Network (NN) and Support Vector Machine (SVM). As the learning rate is high in machine learning, then the system's accuracy goes high, but increases the area and cost overhead. Fusion-based methods have been proposed in further work to overcome that training limitation, based on Harris corner, Speed up Robust Features (SURF) and DWT + PCA system model where only 10% training sample has been taken on Essex database, and 99.45% accuracy is achieved. Creating the Fusion rule requires some hit and trial methods that may not be Universal in every database. To overcome this limitation further an efficient Hybrid method proposed which elaborates the local features Linear Binary Pattern (LBP), Histogram Oriented Gradients (HOG), Gabor wavelet and global features (DWT, PCA) of the face. Further, this feature

K. Raju (✉)
Department of Electronics and Communication Engineering, Narasaraopeta Engineering College, Narasaraopet, Guntur, Andhra Pradesh, India

B. Chinna Rao
Department of Electronics and Communication Engineering, NS Raju Institute of Technology, Visakhapatanam, India

K. Saikumar · N. Lakshman Pratap
Department of Electronics and Communication Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, India
e-mail: lakshmanpratap@kluniversity.in

P. Kumar et al. (eds.), *A Fusion of Artificial Intelligence and Internet of Things for Emerging Cyber Systems*, Intelligent Systems Reference Library 210,
https://doi.org/10.1007/978-3-030-76653-5_11

trained with Neural Network classifier to obtained better accuracy nearly 99.40% with single image training from each class.

Keywords DWT · PCA · ICA · LBP · HOG · GLCM · Harris corner

11.1 Introduction

However, the face tends to be a simple target to identify and recognize through the eye, but artificial intelligence is not yet sophisticated enough to efficiently accomplish the role. As the source of a face is typically an entity that collects pictures, some variations and complexions remain with the image, such as noise, movement, etc. Several approaches use any or another algorithm to locate resemblance in the face model. The test picture and most of them effectively obtain more substantial similarities in the test [1]. However, a single algorithm cannot reach optimum performance everywhere given the varied scope of applications and method of image sourcing. After using the right algorithm for a specific mission, facial recognition problems must be countered by an application. The skill of recognition strategies fits the same trend as identification, and the increasing demands of businesses are finding changes in patterns of recognition. Four datasets-ORL, Essex, YaleB and Indian are tested in several experiments to achieve good results in multi-purpose domains. This research aims to conduct a comparative study of all the techniques with current precision methods and incorporate a real-time face recognition device on the Raspberry Pi 2 CPU (central processing unit) [2].

11.1.1 Problem Statement

Achieving high performance for a face recognition system in the real world has been a problem open to researchers for recent years. Inappropriately, uncontrolled conditions such as illumination variations, occultation, and facial expressions and poses variations significantly influence the performance of face recognition systems particularly those based on 2D information, as this kind of knowledge depends mainly on sources of light, in addition to the 2D image or the color image does not represent the shape of the face. It does not treat the beginning as an object, while these systems are sensitive to the real uncontrolled environment [3].

The variation of poses of the head is a significant problem for the recognition of a face. Correcting the posture and estimation of the head's rotation angle are necessary processes to solve these problems. However, because of the mathematical complexity and high costs in terms of memory and computing time, the development of a robust automatic face recognition system with the variation of poses is considered a big challenge for facial biometry researchers [4].

Another difficulty for automatic face recognition systems is the representation of facial images and the extraction of the most discriminating features to build people's biometric signature. In this research work, this signature is in the form of a character vector [5]. Several methods have been developed for extracting features that are global or local methods. Local descriptors are recently used as very effective image representation methods; they are proposed initially for texture classification. They are used for facial image analysis. This thesis involves the study and evaluations of five best descriptors, used recently in the literature.

More recently, the development of facial biometrics research has focused on using the 3D facial surface and the shape of the face to represent the most discriminating features with an increase in the dimensionality of the characteristic vectors [6]. To reduce the impact of such problems, dimension reduction is used in most face recognition systems. Dimensionality reduction plays an essential role in information processing, particularly in facial biometrics systems that require rapid execution and high accuracy. Several approaches have been proposed in the literature; note that the two algorithms, Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) are basic algorithms for most of the proposed approaches [7].

The main problem of research work concerns uncontrolled conditions in the automatic face recognition system: the variations of illuminations, facial expressions and poses. As well as extracting the discriminative characteristics of facial images based on local descriptors using depth images. However, the proposed work examines the data reduction process's role in developing a robust, efficient and accurate automatic face recognition system.

11.2 Literature Review

The biometric recognition techniques also termed as biometrics, identify an individual with their physiological and behavioural patterns. Similarly, the process of identifying an individual by its face has called as face recognition. The motive of recognising a look is identifying an individual from a similar class of species. The individual has determined by several face features that are unique for an individual. Face recognition is a vast research area with numerous problems. These are due to its application in different fields such as Mugshot album, surveillance camera, identification card, access control card etc. The face classification when firstly introduced in [8]. In this proposed paper, the author started gathering the faces the database and classified it according to its deviation from the norm. This generated vectors which could compare with other database vectors. This is called multimodal classification. Due to the vast advancement, FR systems have used in real-time applications widely [9]. Such a vast improvement in face recognition is because of the following reasons:

- Development of various algorithms
- An extensive database for experiments (e.g. FERET, Yale, ORL etc.)
- Various performance evaluation methods.

As we know, each coin has two sides. Similarly, face recognition technology also has some drawbacks. If a system has a static image, it will be easily recognised, but it is quite difficult to recognise the shot if given a video frame. Similarly, suppose the system is commanded to identify one or more person from a single image. It is quite complex to compare all the faces from the database and recognise them accurately.

While comparing the queried image and database image, many aspects need to be considered. These are:

1. Firstly, a person who seems to be co-operative claims to be "someone". This means there is no need to verify the complete database images (model images) with the incoming/queried image (probe image). Only the database image whose identity is claimed by the probe image needs to be verified. For recognition, all database images have compared with the probe image, which is comparatively extensive.
2. Secondly, this automated FR system should consume less time to be accepted in real-time practical applications.
3. In the final step, the images of different persons from the training database have taken for comparison. Only when an imposter (most alike person) is present, needs to be recognised more carefully.

Face recognition technology belongs to biometrics, where the person's identity is matched with the database and thus verified. This verification depends upon the person's facial features. On general basis biometrics field uses fingerprint, iris-pattern also for identification [10]. The use of iris-pattern recognition is less than other biometric methods because there is a risk of protectiveness for one's eyes. Face recognition system is a passive system which does not interrupt the natural verification process. The face recognition process has carried out into three steps:

(1) Firstly an observation is done by the sensor. This observation gives some unique signature about a person's identity, also known as 'Biometric signature'.
(2) Secondly, the sensor and observed data depend upon the type of biometric device used. Now the biometric signature is normalised to get the database signature and biometric signature into the same format, i.e. image size, view, resolution etc.
(3) Finally, the matching process has carried out. Here the normalised signature is compared with the database signatures. And the scores are allotted for each match. The match having the highest score is declared to be the perfect match.

Each biometric system has a different way to deal with the similarity score. The face recognition process initiates with the detection of the face area in the image. Sometimes, the image's background is more crowded, leading to wrong face recognition if a face is not detected correctly [11, 12]. The face detection process includes detecting the face area, normalizing the image parameters (like illumination changes, views etc.), facial appearance etc. The results are then further processed using modelling schemes.

Face recognition technology has its applications mainly in two field's i.e.

- Law enforcement
- Commercial field.

FR technology is mainly used for mugshot albums in the law enforcement field and matches the surveillance images. Whereas, in commercial applications photograph of a person on ATM cards, credit cards, passport, photo identity, driving license etc. is matched with a real-time image for granting access to that person.

Though both fields have different face recognition uses but it faces certain constraints during its processing. The face recognition technology processes in two phases:

(1) Face detection and Normalisation
(2) Face identification/Matching.

An algorithm or a system consisting of both phases is known as fully automatic face recognition algorithm (For example, only the face image has provided). An algorithm or a system consisting of any one of the phases is known as partially automatic face recognition algorithm (For example, in this algorithm, the face image and the eye co-ordinates are also provided). The development of face recognition technology permits an organisation to perform frontal, view-tolerant and profile recognition. The type of award depends upon the image type and the type of algorithm used. The frontal recognition uses classical strategy, whereas the view-tolerant recognition uses a sophisticated manner to perform recognition based on some geometrical, physical or statistical features. Profile recognition is an individual recognition system which has a small significance in honour [13]. These recognition systems are efficient for fast and large databases to lessen the load and computability for a particular or hybrid algorithm. These hybrid algorithms have a special status among other face recognition algorithms because they combine various algorithms serially or parallel to avoid stand-alone components' drawbacks. Face recognition techniques can also categorise based on models or exemplars. Models have used differently in different researches. In [14], models are used to compute the quotient image, whereas in [15] models are used to check the active appearance. These models provide information about the class, and they also offer a way to deal with appearance variations. Exemplars have also been used for recognition such as in [16] both training and matching images have been used against probe image. The methods using models do not use exemplars because they cannot be employed together as they are not mutually exclusive. An approach was proposed in [17] to combine models and standards. These images were further used as exemplars in a learning phase in which models were used to synthesise training images.

Considering pose invariance again face recognition can be categorised as:

(1) Global approach
(2) Component-based approach.

In a global approach, the whole face image represented by a single vector has given as an input to a classifier. Various classifiers have used in previous research such as Fisher's discriminant analysis [18], Neural Networks [19], minimum distance classification etc. For front view images, global techniques have proved themselves well. But they are not immune to pose variations. Therefore, they get affected by the rotation of the face. To overcome this issue, the addition of an alignment before the classification stage is an option. To align the reference image and input image needs more computation. The correlation between the two ideas could found through critical points such as lip corners, nose, eye-balls etc. On this correlation, the input image can be deformed (warped) according to the reference image. Warping can be performed by computing affine transform. In [20], active-shape models with model faces are used to align images. In [21], a combination of SVM and partially automated alignment were proposed. An alternate for this approach can be the classification of local facial components. This component classification approach is to reimburse the pose variations by permitting flexible relations among the classification stage components. Face-recognition was complete through independent template matching of three critical points of the face, i.e. eyes, lips and nose. Because the geometrical characteristic was comprised in the system, configuring the classification stage components was abandoned. An extra alignment stage with a similar approach was proposed in [22]. The implementation of the geometrical model using two-dimensional elastic graph was shown in 42. This technology of face recognition still lacks in some aspects like pose and lighting variations. Though there are many methods and algorithms proposed until now and they give a promising performance, some problems remain. Hence, the performance of matching is degraded because of the reasons mentioned above and is low compared to other biometric matching performance (e.g. fingerprint, iris recognition). Error rates are in the range of 2–25%bwhich is very common. The system can perform better if it has used in combination with other biometric computations. According to ref. [23], existing recognition systems perform well if test images and training images have the same image capturing conditions. But if these conditions differ for test images and moving ideas, the system will not be capable enough to deal with these changes. These changes can be lighting variations, head-pose modifications, accessories, hairstyles, facial expressions etc. The approaches can be further categorised based on interpretations, i.e., canonical forms, invariant features, variation-modelling [24].

1. "Canonical form" approach "normalises" the changes by synthesising new test images in canonical/prototype form or by the creative transform. Then these prototypes are used for recognition. In the examples of this approach is depicted. In [25], the probe image captured under random lighting conditions has again processed from frontal illumination. Both states have then compared with one another.
2. An invariant feature approach, the characteristics that are invariant to variations are analysed. The example can see in reference [26], in which the quotient image is consistent with the lighting conditions and can recognise a person accurately under varying illumination.
3. In variant-modelling approach, the main motive is to study the extent of variation in a particular subspace region. These can cause to define and decide the parameters that are mandatory for subspace. Then a nearest (close to test image)

subspace is chosen for recognition after mapping. In spite, this recognition can estimate the pose and a person's identity. The example of this system can be seen in [27]. Even after developing so many techniques and research efforts, the face recognition field's problems remain unsolved.

All three approaches work well for a particular variation. For other variations, the performance of the system degrades gradually. It can explain well with the following example that a feature invariant technique is invariant to pose and face expressions until they are constant. Still, as soon as the pose or face expressions change, the method fails to remain consistent. In some cases, this is not an issue like granting access etc. because both the test image and training image have captured under the same circumstances. But it cannot recognise the idea in general conditions, and hence none of the three techniques is reliable.

Furthermore, it is also not sure that these techniques can be used in combination or not to avoid the drawbacks. Some of the methods have behaviour to remove others. Like in [28], the symmetric shape-from-shading way depends upon frontal face symmetry. But it is not clear how this technique will work in case of side-view of a face or a condition where balance is not present. From this research, two essential facts have observed, and they are:

(1) Firstly, no feature/set of features are correctly or entirely invariant for all the variations that can occur to an image.
(2) Secondly, if any system has more training images, then many techniques will perform better.

11.3 Face Recognition Techniques

National Institute of Standard and Technology (NIST) of the U.S. performed a survey to evaluate the FR system's performance. According to that survey, the best FR algorithm's ability experimented on 1.6 million images to recognise a person or object correctly (known as True Positive Identification Rate) is 92.3%. The experiment was conducted on various datasets started from the FERET database. Suppose face recognition is considered for criminal case investigations. In that case, the faces' evaluation can be affected by some factors like ageing, varying facial expressions (smiling, sad, tensed etc.), changing orientation angles and accessories such as (glasses, hat, moustache or beard etc.). These variations have depicted in Fig. 2.1 As per the growing development of face recognition technology, the FR system's accuracy is hardly affected by the above effects. NIST's evaluation results state that the current face recognition algorithm is much better than the earlier algorithm of time 2001. Thus the existing FR algorithms are reliable enough for being used in criminal case investigations [29]. As discussed above, face recognition technology required for criminal case investigations should be more advanced than general face recognition systems. This is because the images given for forensic analysis have infrequently shot under non-ideal conditions, leading to false rejection or false acceptation. In this paper

[30], the improvements/developments in the general face recognition system and the forensic face recognition system have discussed [31]. According to this article, to avoid false rejection or false acceptation, the following factors should be considered during forensic face recognition:

1. **Ageing**
   Human face changes according to age. Thus ageing is a factor that should be considered during face recognition [21].
2. **Facial Marks/Scars**
   Some marks or scars become an identity for a person. It may be from birth or due to some accidents. But in the FR system, it plays an essential role in identifying the correct person [10].
3. **Sketch**
   A sketch of a suspected person has generated if his/her photograph is not available. The illustration differs from an original picture of a suspected person because of inaccurate description from the witness or wrong understanding of an artist drawing the sketch. It can sometimes lead to false acceptance.
4. **Image Captured by Surveillance Cameras**
   The video frames or images captured by CCTV/surveillance cameras sometimes help to identify the person. But sometimes the image captured is burred not clear. It could mislead the face recognition system [32].
5. **Near-Infrared Face Recognition (NIR)**
   Near-Infrared Face Recognition (NIR) image method has proposed to overcome the illumination effects. According to Klare and Jain, the NIR method obtained 94% true accept rate and 1% false accept rate. Hence, the NIR technique should be considered for forensic face recognition. This paper studies the various face recognition algorithms such as trainable, non-trainable and commercial in 1, 2 and 3 algorithms in number. These algorithms have evaluated on a partitioned gallery, which has demographic cohorts in its every part. These parts are sub-categorised based on gender, colour complexion, age etc. The experiment conducted shows that non-trainable and commercial algorithms are less accurate in recognising similar cohorts. Whereas trainable algorithm is less affected by the demographic cohort. Hence the use of dynamic face matcher selection comes into the picture. In this method, various FR algorithms are available to select the relative demographic information extracted from the probe image. This method gives higher accuracy in many FR scenarios.

Mostly the frontal face images are considered for research of face recognition algorithms. The benefits and drawbacks of all methods such as Eigenfaces, Hidden Markov Model (HMM), Neural Networks (NN), Dynamic Link Architecture (DLA), Geometrical Feature Matching (GFM), Fisherfaces, Template Matching (TM), Elastic Bunch (EB) etc. are discussed. Each of these methods has discussed and analysed one-by-one as below.

11.4 Eigenfaces

One of the vital face recognition techniques is Eigenface (also called as Karhunen–Loeve expansion). The face pictures have also represented through principal component analysis in [33]. In this paper, according to the authors; it is possible to recreate the face image using a set of weights for each face and standard face image (also known as Eigen picture). The face image is projected on to the edge picture to achieve consequences for each face. Mathematically, eigenfaces can be defined as the principal components of the distribution of faces or the eigenvectors of the set of face images' covariance matrix. Eigenvectors ought to represent various changes for different looks. Eigenfaces are used in linear combination to describe each face. It can be estimated through the use of eigenvectors which have the highest eigenvalue. Such best' M' eigenvectors construct M dimension-space (known as face-space also).

An experiment conducted taking 2500 images of 16 different persons with different backgrounds shows a 96% accuracy for varying illumination, 85% accuracy for varying orientation, and 64% accuracy for varying sizes. Though this approach gives a powerful performance using the correlation between image and variable illumination, the correlation between image and running illustration does not satisfy the face recognition result. For Eigenface methodology, tilizedng illumination (lighting effect) is a necessary step. Another new approach has suggested three images having different illumination have considered for calculating the covariance matrix. Gu, Wenfei, et al., have worked further improved from Eigenface to eigenfeatures which incorporates face organs as features such as (lips, nose, eyes etc.). This modular eigenspace method is less affected by the change in appearance than other standard eigenface methods. Another experiment was conducted on the FERET database taking 7562 images of 3000 different persons, resulting in a 95% accuracy recognition. Hence it is proclaimed that an eigenface method is a practical approach with faster and simpler strategy.

Koc, Mehmet, and AtalayBarkana suggested that ears can also prove to be better than face for biometric recognition. Earlier similar work was done with ear and face using PCA (principal component analysis), but it resulted in low ear image recognition. Hence, in this proposed paper 58, the Eigenface and linear method is used, which results in 70.5% for face and 71.6% for ears when experimented. And when both were considered together for multimodal recognition, it gave 90.9% recognition result. The multimodal biometrics work has been extended. Another similar approach could be seen where face and fingerprint and face and voice have been tilized for multimodal face recognition.

11.5 Neural Networks

Neural Networks has grabbed so much attention because of its non-linear network recognize. Hence, it proved to be more capable of feature extraction as compared to other linear approaches. WIZARD is an adaptive technique among artificially generated neural networks with a single-layered architecture. It comprises of an individual network for storing every single information. The path of designing a neural network for efficient face recognition is quite tricky because it depends on the application for which it will use. In [34], MLP and convolutional NN are used respectively for face identification. Therefore, a neural network must be a biological neural network that consists of actual biological neurons and an artificial neural network that finds solutions with artificial intelligence (AI).

1. Face Detection: This is the step where a person's face has detected by skipping the background image.
2. Eye Localization: This is the step where both the eyes' position is determined using feature vectors.
3. Face Recognition: PDN network is not interconnected completely. It partitions the network into 'K' number of subnets. One subnet recognizes one person from the database. The face subnet has a total of the neuron outputs. It uses Gaussian function for neurons to estimate the likelihood density.

The PDNN in its learning stage can be considered as:

Phase I—In this phase, each sub-network has trained by its face image.

Phase II—This phase is known as decision–based learning phase. Here the subnetwork parameters are trained by some other face images using particular image samples. It does not use all images for training, but the wrongly classified patterns have only been used.

11.6 Geometrical Feature Matching

Here, the set of geometrical features has computed from the face image. This technique is thus known as a geometrical feature matching technique. This is the technique because the face identification is possible at the low resolution of 8×6 pixels. After all, the general geometrical feature information is sufficient for recognising the image. The face organs such as eyes, eyebrows, lips, nose etc. have represented by the vectors, which describes the overall configuration. In [35], similar work on automated face recognition system was executed using geometrical features. This FR system's peak recognition rate was 75% taking 40 images of 20 different people (2 images per person—1 training/model image, 1 testing image). According to the reference manual feature extraction in the FR system could give satisfactory results. In geometrical features such as nose length and width, lips position co-ordinates etc. were automatically extracted. 35-dimensional vectors extracted around 35 components and recognised using Bayes classifier. When an experiment was performed taking 47 persons, it provided a recognition rate of 90%. Another technique known as the mixture-distance method was applied to a database of 685 people which provided accurate recognition of 95%. Thirty distance measures are extracted manually and represent each face image.

Gu, Wenfei, et al. makes use Gabor wavelet transform to decompose image and identify the feature points for face image, which reduces the storage space requirement. Usually, 35 to 45 such feature points have created. The topological representation of these feature points has used to match the test image with the database image. The recognition rate was 86% for identifying the right person and 94% cases are such that the person's face matches with the top three matches. Concluding this, it can be said that matching of geometrical features has based on the distance measurement between two elements which is more desirable in matching queried image with the Mugshot database. Although it depends upon feature location accuracy. Existing feature location methods need more computation time and still does not have rightful accuracy.

11.6.1 Fisher Faces

Another face recognition technique is, which has used widely. It is an appearance-based method. R.A. Fisher developed Fisher analysis in 1930. A study demonstrates the better results successfully obtained in face recognition. Another FR approach is the LDA approach, which determines the base image, increasing the between-class scatter and within-class scatter ratio. This ratio calculation consumes a lot of processing time. There is one drawback of this technique, and that is the scattering matrix is always single. If the illumination or pose conditions changes, it will maximise the error detection rate because of the number of pixels that are more in number than the number of images. Thus to avoid this issue, many other approaches were proposed. Fisher face approach is one of Belhumeur et al., which can overcome this problem of varying illumination or pose because it removes the first three principal components responsible for light variations. Hence it is more robust to lighting changes. Fisher's face makes use of within-class information which reduces variations within the class. Thus it proved to be a successful method to resolve the given problem [36]. The PCA and LDA were used with the Fisherface process, which generated a subspace projection matrix (similar to dimension-space/face-space in the eigenface method). Fisher face method uses within-class information and reduces the variation but increases the separation among classes. Identical to the eigenface method, the initial step in fisher face is to reshape the image array of size (NXM) into an image vector of length ((NXM)X1). Fisher face is the enhanced version of the eigenface method but with better classifying ability. Here, the training image set could be trained to handle different persons' images and other expressions. Fisher's face gives more accurate recognition as compared to the eigenface method. Determining projection face space is more complicated in Fisherface than in the eigenface method. This is one of the drawbacks of fisher face method.

11.6.2 Template Matching

In this technique, an image under test is represented by a 2D-array whose intensity values have been compared using a suitable measure unit like Euclidean distance. Here, the entire face has defined by a single template. Other advanced versions of template matching algorithm are also available. An individual's face could be represented from different pose/viewpoints using more than one feature template. It could also be defined from an individual view utilising several smaller templates. The grey level of the image needs to be dealt with appropriately before the matching process. Similar work was done using four templates to represent the nose, eyes, lips and the whole face. The experiment was conducted on 188 images of 47 different persons for template matching and geometrical matching. Both methods' performance outcome was compared, and it was seen that template matching (100%) has a superior performance over geometrical matching (90%) approach. Template matching algorithm has a complex computation and its complex description. In general comparison, the template matching approach is far better than the feature matching approach. Though the face recognition system bears some discrepancies, this tolerance yields a unique face identity for an individual. There is no such algorithm which is perfect and has no drawback. Thus further improvements are needed to enhance the FR system performance, which could be used in real-time applications.

11.6.3 Morphable Model

This technique is the vector representation for human faces which is shape and texture vectors combination. To recognise the three-dimensional object correctly, the use of 3D models is necessary. 3D Models could be used on images in two ways. In the first case, the recognition is based on model coefficients and is free from image conditions. The model coefficients here represent the shape and texture of the object/face. In the second case, the 3D-face could be reconstructed by generating synthetic views from trained images. These views have then transferred to other position-dependent face recognition system.

Li, Shaoxin, is proposed that the three-dimensional shape, image parameters and texture can be estimated from a combination of deformed 3D-model and computer graphics. In this algorithm, rotation and lighting changes are easy to be handled by a single model. Though, the illumination changes can cast shadows which will affect the human skin appearance features. Hence the 3D-morphable model is introduced, which can learn face properties during 3D-scan. It represents the shape and texture of the face through high-dimensional face vectors. The algorithm proposed automatically detects the head orientation, face orientation, lighting direction, camera position etc. This is possible because of the initialisation procedure, which uses co-ordinates between 6–8 feature-points. This, in turn, increases the reliability and robustness of the FR system. When the experiment was conducted on CMU-PIE database, it showed 95% accurate recognition for side-view images. In contrast, when the investigation was born on the FERET database, it showed 95.9% proper recognition for front view images with correct head-pose recognition.

11.7 Support Vector Machine (SVM)

In this approach, the key-points for face representation have selected on a manual basis. The feature vectors have then brought to a computable level. The SVM classifier is then used to handle both small and high dimensional samples to classify such feature vectors. In this research, a face recognition Human–Robot-Interaction system has implemented Hidden Markov Models (HMM) combined with SVM. Only the full pose have taken under consideration for this face detection technique. The two significant benefits of this algorithm are:

(1) It does not require any manual selection for face or head pose estimation.
(2) To improve the normalisation performance, the image is classified based on whether it is in the front pose.

The experiment was conducted on various datasets, and as a result, the system was able to identify the face accurately with the recognition rate of 99.67%.

In [73], the two conventional Support-Vector-Machine methods have used. Those are:

(1) One-against-One
(2) One-against-Rest.

This research work has divided into three sections.

(1) The Gabor wavelet process eliminates the illumination and robust effects of images.
(2) The large size of the feature data has reduced by using the bilateral two-dimensional-LDA method.
(3) As a final step, the classification of face recognition features has carried out using an SVM classifier. The actual aim of SVM classification is to handle binary/multiple classifications.

The One-against-One and One-against-Rest method has applied in the matching process. The experiment was conducted on the ORL database, and it was found that the One-against-Rest way gives more accurate recognition than the One-against-One method. Kamal has proposed here to use PCA for feature extraction and SVM for pattern classification. SVM is a widely used classifier introduced to tackle recognition patterns. The experimental setup contains 400 ORL database images of 40 persons captured under distinct circumstances like light variation, varying facial expressions, different face orientations, with or without glasses etc. Various SVMs have used till now like Polynomial-SVM, Linear-SVM, Radial Base Function SVM

(RBF-SVM). These SVM classifiers have compared to one another. The SVM classification compared to MLP (Multilayer perception, a standard eigenface classification approach) category shows that SVM has a better performance over MLP. But when compared among SVMs, P-SVM and RBF-SVM have a better understanding of L-SVM.

11.7.1 Harris Corner

Shang, Li et al. have proposed Harris Corner method used for palmprint recognition. The corner points have lined using orientation features and distance. Matching is done based on fuzzy logic. This algorithm filters the resulting corner points. The algorithm identifies the palm print using orientation and distance features. This algorithm results in a higher recognition rate with more than 50% less memory requirement. A new pyramid-based-FAST-corner detection has proposed a superior version of FAST detector. This pyramid-based-FAST-corner detector detects the face organ corners, and its result has compared to other corner detection techniques such as (FAST, SUSAN, Harris, SIFT etc.) As an initial step, face corners and other unnecessary corner points have filtered. In the next step, based on organ corner points the organ such as eyes, eyebrow, lips etc. ten such points have highlighted.

Further in the final stage, similar ten key attributes have used to locate the organ's centre. In this manner, the face's model has constructed through triangulation and geometric features. The experiment has conducted over 200 sample images, and it is seen from the results that this algorithm can locate key points accurately for both grey and coloured illustrations. The recognition rate for JAFFE is 94.95% and for MMI is 90.95%.

Mathe, Stefan, and Cristian Sminchisescu [37] have worked on the Harris Corner detection to identify the human eyes from the given coloured images. In the first step, the detection has done through YCbCr conversion. The Cb component here is useful eye detection. The human face has extracted from the preprocessed image, and the eyes have detected by applying the Harris corner method in the second step. This study reveals that the Harris corner method uses only two corner points to see the eyes with the accurate detection rate of 88% and proves itself suitable enough to be used for further detection.

Eye detection plays a significant role in Human–Robot interaction (HRI) system. But in this paper, eye detection is performed using shape and colour information about skin (known as skin patches) in combination with Harris corner method. Here Harris corner method is used to figure out the region-of-interest in the skin patch. This work has influenced from the previous work on "skin patch detection". In this proposed scheme, an RGB image has been used to detect the eyes with the relative information of corner points, colour and edge (shape). The experiment was conducted on the AR database and the champion database, which shows that the proposed scheme is faster than the previous schemes with the average time of 2.53 and 0.21 s per image and the detection accuracy of 100% and 89.5% for the AR and champion database. Above we have seen the Harris corner related work for eye detection. But in Royce et al. has used Harris corner and FAST corner methods for recognising the smile automatically. In this proposed work, the lip corners are taken as reference points to detect the smile accurately. The experiment has conducted on Video, Image and Signal Processing (Visio) dataset, and the results of the two methods have compared to each other. The results show that the Harris corner detector gives a higher recognition rate of 77.5% than the FAST corner detector (recognition rate of 72.5%).

11.8 Speeded-Up Robust Features (SURF)

In the face recognition field, for Human–Robot-Interaction (HRI) system it is difficult to identify a personality accurately compared to humans due to vision problems encountered because of varying illumination, varying expressions, varying background etc. To resolve these issues, and efficient technique has proposed in. In this proposed algorithm, once the skin region is successfully detected, the face region is detected using the ellipse-fitting method. Features of the face region obtained from the ellipse-fitting process have extracted using SURF (Speeded-up-Robust-Features) classifiers. Further, the queried image has compared and matched to the database image. The proposed algorithm has experimented on Caltech's face database, and the recognition rate of 93.75% has achieved for different resolutions [38].

Li, Jianguo, Tao Wang, a SURF based novel boosting cascade framework has proposed. Three contributions are essential here:

- SURF features have used for faster face recognition
- AUC has used for cascade training as a single criterion, which also gives fast training convergence.
- A real-time example has shown to train fast and accurate cascade face detector from billion sample images within 1 h.

In [39], salient features have used for face recognition or object recognition. In the proposed algorithm, SURF descriptors have used to generate feature vectors, and SVM classifiers have used to classify feature vectors. One classifier verifies whether the feature vectors belong to face image or not [40]. This is done in the first layer. In the 2nd layer, each object in the face like eyes, lips, nose etc. has assigned labels. These are known as component labelling [41]. This technique gives high recognition rates. However, there are further chances of improvement in future [42].

Feature detection, Feature matching, transformation are the necessary steps required for image alignment [43]. These steps have based on image features and image reconstruction. Matching and feature extraction are two essential steps demanded in various image applications [44]. In this paper, the Scale Invariant Feature Transform (SIFT) and Speed Up Robust Features (SURF) methods have proposed. An experiment was conducted to compare SIFT and SURF, and it was seen that SIFT had detected more features than SURF. But SURF performs better than SIFT in terms of speed.

A feature detection scheme "SURF" has been researched in this article. SURF (Speeded-up-Robust-Features) was motivated and derived from SIFT (Scale-Invariant-Feature-Transform). Both SIFT and SURF have good performance over feature detection and are faster than previous detection schemes. Seeing its version, Xu et al. decided to study and implement SURF feature detector and SURF feature descriptor. Authors also suggest implementing SURF comparator to group similar feature pairs. Since this comparator is not featured dependent but based on code, hence we can use other feature types like SIFT etc. to evaluate its performance.

In this research paper, SURF has been introduced as a novel method. SURF proved itself as a robust technique which can perform better and faster than the previously submitted schemes. SURF can be implemented by.

- Convolving image through integral images
- Strengthening the current detectors and descriptors
- Simplication of the used methodology

11.9 Independent Component Analysis (ICA)

ICA (Independent Component Analysis) is a new method introduced in the field of face recognition. It is a superior version of PCA. The architectures of ICA were analysed using PCA. ICA has Architecture I and Architecture II. Study reveals that Architecture I has vertically centred PCA whereas Architecture II has whitened PCA with horizontal centring process. Using these two architectures as a baseline for ICA increases the robustness of the face recognition system. In this paper, the experiment has conducted on the FERET database, AR database and AT&T face database. Though there is no significant difference between ICA and PCA, a small number of changes could be seen in some cases. ICA entirely relies on PCA as the centring and whitening process has a great deal of impact on ICA performance.

A robust method known as locally salient ICA (LS-ICA) is proposed in this paper to improve the performance and eliminate distortion and occlusion. This algorithm divides the original image into parts and then extracts the image information from them. The salient features of the face part of the image have used, which benefits from using the idea "recognition by parts". In LS-ICA, the partitioned image is created by adding extra constraint information during kurtosis ecognizedn. When compared the LS-ICA technique's performance with LNMF (Localized Nonnegative Matrix Factorization), LFA (Local Feature Analysis), PCA, ICA Architecture I and ICA Architecture II; LS-ICA always shown a better result.

Thang, Nguyen Duc, et al. is concerned for dimensionality reduction for face recognition. ICA is one of the methods that decrease the dimension of the image. Also, the proposed method Locality Preserving Projection (LPP) is good at reducing image dimensions. These two methods have compared, and the results are analysed. An experiment was conducted on the Yale B database (with 64 varying illuminations) and AT&T database (with varying facial expressions). The performance evaluation states that ICA is better than LPP under the variable definition, whereas LPP is better than ICA under running facial expressions due to its better recognition rates. A standard face recognition method (ICA) that can opt according to the changing face expressions is proposed and implemented in this paper. This is due to the traditional method's ecogniz of treating the varying face expression as noise. Reconstruction of different facial expressions is done based on two KIM conditions and then trained to get a single sample. Then the whitening process is applied to these samples using eigenvalue decomposition. This method provides a better result and recognition rates. Can use this method for compressing image or for MPEG-4 animation etc.

Singha, Anu, et al., GaborJet-ICA technique has proposed. Here face image has convolved with 40 Gabor wavelets. Feature vectors have derived from GaborJets that are the facial key-points. These GaborJets have later on transformed as its ICA and PCA components have computed. The experiment was conducted on ORL database taking subspace and ICA as its parameters. Observations were taken for the varying range of subspace dimension and no. of independent components. GaborJet-PCA and GaborJet-ICA were compared, and it was found that GaborJet-ICA performs better with accurate recognition of 84.5% than GaborJet-PCA with special mention of 82.25%. In this paper, ICA aims to feature extraction of the original image from the raw image data. These components can't be entirely relied upon because ICA components do not appear in a particular order. Thus it can't be said that which feature is more important. To enhance the ICA performance, it is essential to select the components having a good impact, whereas the elements having a harmful effect or are noisy can be eliminated. Thus two methods are introduced in this paper [23] to get the better performance result of ICA by selecting and removing the respective ICA components. First is Component Subspace Optimization, and the other is the Sequential Forward Floating Selection (SFFS). In future, recognized of independent components can be expected in ICA face recognition system. In the FR system, there are numerous methods such as PCA, ICA, LDA, SURF etc. for dealing with front-view images even though there is a lack of information.

In some cases, the recognized face varies from user to user. Thus a modified version of ICA algorithm is proposed. In this modified ICA, the information about the face database has already known. But the test sample and the training samples are not similar. An experiment conducted on the FERET database reveals that the proposed algorithm saves the computation time and the system's memory.

11.10 Results

1. Acquisition of the image: Depending on the system used, it tends to be a still image, a video frame, a three-dimensional image, etc.
2. Face detection: Uses object recognition algorithms that detect whether there is a face in the image. Provides the location and size of the face. This uses Viola, Jones technique which is the standard one.
3. Preprocessing: When a face is resolved on the picture, the normalisation process is performed. Face components such as size, pose, and illumination is found. To

normalise face images, diverse guidelines can be taken after, such as the nose's position, the separation between the pupils of the eyes, and the lips' size. To improve the framework's execution, procedures, such as decreasing the picture size, changing the picture to grayscale, or a low-pass filter, are utilized if the image resolution is too high.

4. Extraction of the characteristics: After the picture is processed, the picture's characteristic vectors of coefficients will be calculated depending upon the method utilised.
5. Recognition: The technique mentioned above has used to detect the facial image and face features extracted using Local binary pattern (LBP) and PCA methods, which are an appearance-based approach depending on pixel values of facial images. At last, the extracted component vector has compared with the feature vectors extracted from the faces database. If it finds one with a high percentage of similarity, it returns the face's identity with that person's name; if not, it indicates an unknown face, as shown in Fig. 11.1.

Implementation testing of the system In this work, an application for real-time face recognition is implemented in Python over the RPi2. To perform this, the library OpenCV that supports image processing has been used. The algorithm implemented for the real-time face recognition problem is divided into two different, independent modules:

- The training stage, performed at distinct distances and various illuminations and orientations, as shown in Fig. 11.2a.
- The recognition (testing) stage, performed to identify the working range of the system, and its display's that person with his name, as shown in Fig. 11.2b.

11.11 Experimental Results

The outcomes of the categorisation for five different persons for frontal images are taken. To determine the correctness of the developed system in real-time, we examined some of the person images by capturing their facial images, through webcam connected to Raspberry Pi2 and got the expected outcome with the person's name below (Fig. 11.3).

11.12 Conclusion

Automatic face recognition has been an active area of research over the last four decades. Face recognition has many applications of considerable importance, such as biometric identification, surveillance, human–computer interaction and multimedia data management. Facial biometrics has played an essential role in improving our security by limiting criminals' mobility, preventing fraudulent activities, and

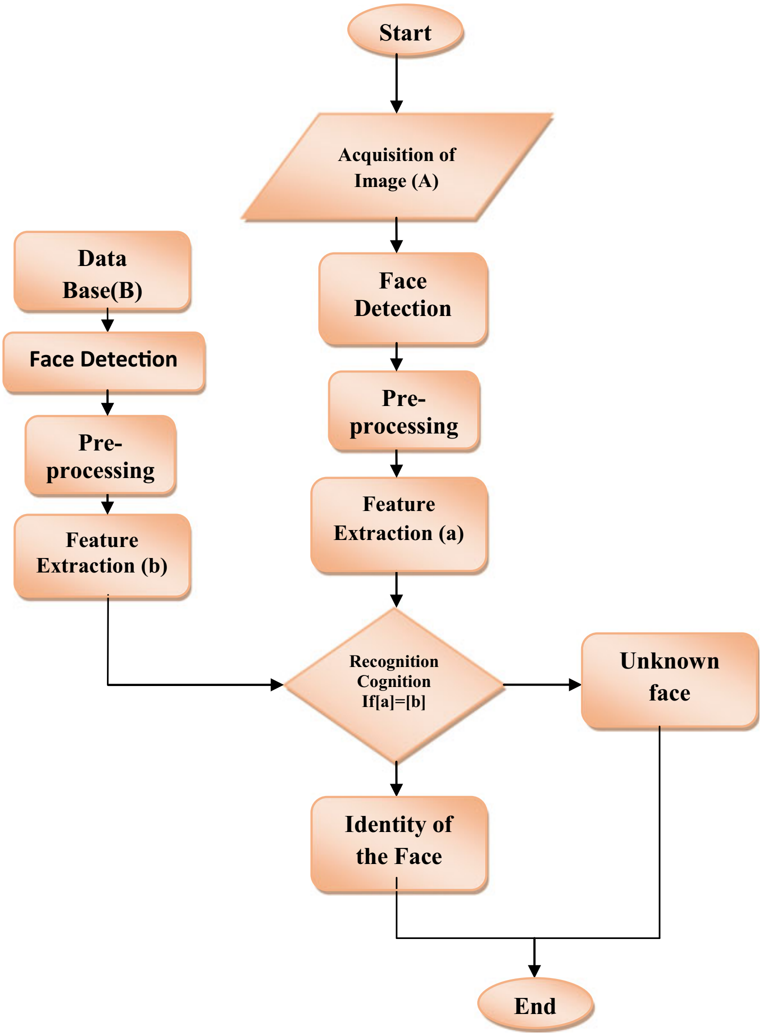
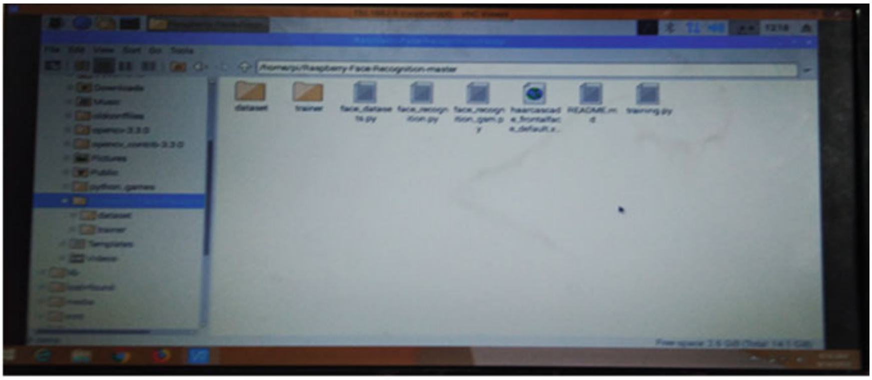


Fig. 11.1 Flow graph of the facial recognition system

searching for missing persons. This thesis focuses mainly on biometric recognition by hybrid fusion of 2D face feature and machine learning. It's demonstrated that the proposed technique beats all compared state-of-the-art and baseline algorithms, which illustrates the robustness of the proposed methods against the appearance variations of articulation, lighting and so forth. The proposed techniques ideally can inspire another new thinking and better approach to handle the face recognition issues.

The feature extraction has processed through 3 stages, i.e. of PCA, ICA and DWT. The PCA resulted in second stage global features, while ICA modified those features

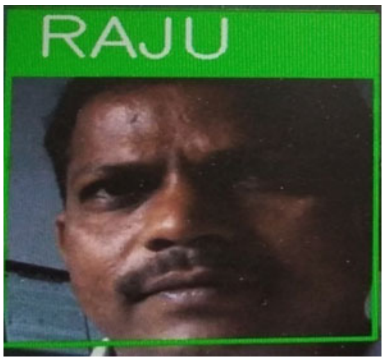


a)

b)

Fig. 11.2 **a**, **b** Training phase in the recognition process

Fig. 11.3 Output of testing image in real-time



and provided local spatially reduced features. For sufficient analysis, the DWT is employed further to ICA for feature extraction, and the final sets of features are classified for face recognition. In recognition, two experiments are parallel conducted; one for SVM and other for Neural Network. The simulation results are compared with the existing works, where PCA, DWT, SVM and other methods are compared for better analysis of the proposed system. It has been observed that the system did not perform optimally with SVM. In opposite to it, Neural Network performed exceptionally well and gave recognition rates up to 96%.

Further, a way to reduce the limitations of single-mode biometric systems is to develop multimodal biometrics. It has been studied the different types of combinations of possible modalities; can use the fusion level in a multimodal approach. The classifications of the characteristics, by the Euclidian difference of other IDs, are achieved by each model. Further, these scores (ID) are fused with the proposed fusion rule to claim the highest accuracy with less training rate. Fusion-based face recognition method gives the precision of around 99.45%. Fusion rule is created based on some hit and trails, which may not be Universal for entire datasets.

Hybrid face recognition, based on the fusion of local information, is proposed. In this texture extraction of image uses LBP + HOG, GLCM, Gabor wavelet decomposition methods separately. DWT has applied in whole train image. Further, the complete extracted features have fused with PCA. It represents faces, which can be roughly reconstructed from a small set of weights and a standard face image. These features are then subjected to a known classifier for its effectiveness in Neural Network.

The developed prototype has been thoroughly tested in Essex, ORL, Indian and YALE B datasets. This approach considered only one image for training from each class. The outcome claims better accuracy by Neural Network (99.40%) than PCA (96.99%). It is said that this research work has achieved a system that meets the objective, initially set up. Though till now, none of the face recognition algorithms has given 100% accurate results under all conditions.

References

1. Jain, A.K., Kumar, A. (2012). Biometric recognition: An overview. In *Second generation biometrics: The ethical, legal and social context* (pp. 49–79).
2. Inamdar, V., Rege, P., & Arya, M. (2010). Offline handwritten signature based blind biometric watermarking and authentication technique using biorthogonal wavelet transform. *International Journal of Computer Applications, 11*(1), 19–27.
3. Choi, J. Y., De Neve, W., Plataniotis, K. N., & Ro, Y. M. (2010). Collaborative face recognition for improved face annotation in personal photo collections shared on online social networks. *IEEE Transactions on Multimedia, 13*(1), 14–28.
4. de Freitas Pereira, T., Komulainen, J., Anjos, A., De Martino, J. M., Hadid, A., Pietikäinen, M., & Marcel, S. (2014). Face liveness detection using dynamic texture. *EURASIP Journal on Image and Video Processing, 1*, 1–15.

5. Hu, H., Ahn, G. J., & Jorgensen, J. (2012). Multiparty access control for online social networks: model and mechanisms. *IEEE Transactions on Knowledge and Data Engineering, 25*(7), 1614–1627.
6. Ding, C., & Tao, D. (2015). Robust face recognition via multimodal deep face representation. *IEEE Transactions on Multimedia, 17*(11), 2049–2058.
7. Unar, J. A., Woo, C. S., & Almas, A. (2014). A review of biometric technology along with trends and prospects. *Pattern Recognition, 47*(8), 2673–2688.
8. Pittman, M., & Reich, B. (2016). Social media and loneliness: Why an Instagram picture may be worth more than a thousand Twitter words. *Computers in Human Behavior, 62*, 155–167.
9. Tyagi, S., & Khanna, P. (2013). Face verification and identification using DCT-NNDA and SIFT with score-level fusion. *International Journal of Biomedical Engineering and Technology, 13*(2), 154–176.
10. Mohammed, A. A., Minhas, R., Wu, Q. J., & Sid-Ahmed, M. A. (2011). Human face recognition based on multidimensional PCA and extreme learning machine. *Pattern Recognition, 44*(10–11), 2588–2597.
11. Luo, M., & Zhang, K. (2014). A hybrid approach combining extreme learning machine and sparse representation for image classification. *Engineering Applications of Artificial Intelligence, 27*, 228–235.
12. Naik, G. R., & Kumar, D. K. (2011). An overview of independent component analysis and its applications. *Informatica, 35*(1).
13. Borgi, M. A., Labate, D., El'Arbi, M., & Amar, C. B. (2013). Shearlet network-based sparse coding augmented by facial texture features for face recognition. In *International conference on image analysis and processing* (pp. 611–620). Springer.
14. Goh, Y. Z., Teoh, A. B. J., & Goh, M. K. O. (2011). Wavelet local binary patterns fusion as illuminated facial image preprocessing for face verification. *Expert Systems with Applications, 38*(4), 3959–3972.
15. Lydia, E. L., Kannan, S., Rajest, S. S., & Satyanarayana, S. (2020). Correlative study and analysis for hidden patterns in text analytics unstructured data using supervised and unsupervised learning techniques. *International Journal of Cloud Computing (IJCC), 9*(2/3).
16. De Marsico, M., Nappi, M., Riccio, D., & Wechsler, H. (2012). Robust face recognition for uncontrolled pose and illumination changes. *IEEE Transactions on Systems, Man, and Cybernetics: Systems, 43*(1), 149–163.
17. Wei, J., Jian-Qi, Z., & Xiang, Z. (2011). Face recognition method based on support vector machine and particle swarm optimisation. *Expert Systems with Applications, 38*(4), 4390–4393.
18. Thai, L. H., Hai, T. S., & Thuy, N. T. (2012). Image classification using support vector machine and artificial neural network. *International Journal of Information Technology and Computer Science, 4*(5), 32–38.
19. Liau, H. F., & Isa, D. (2011). Feature selection for support vector machine-based face-iris multimodal biometric system. *Expert Systems with Applications, 38*(9), 11105–11111.
20. Tome, P., Fierrez, J., Vera-Rodriguez, R., & Nixon, M. S. (2014). Soft biometrics and their application in person recognition at a distance. *IEEE Transactions on Information Forensics and Security, 9*(3), 464–475.
21. Rao, A. N., Vijayapriya, P., Kowsalya, M., & Rajest, S. S. (2020) Computer tools for energy systems. In *International conference on communication, computing and electronics systems* (pp. 475–484). Springer.
22. Smeets, D., Claes, P., Vandermeulen, D., & Clement, J. G. (2010). Objective 3D face recognition: Evolution, approaches and challenges. *Forensic Science International, 201*(1–3), 125–132.
23. Jain, A. K., Klare, B., & Park, U. (2011). Face recognition: Some challenges in forensics. In *2011 IEEE International Conference on Automatic Face and Gesture Recognition (FG)* (pp. 726–733). IEEE, (2011).
24. Babu, N. N., Fathima, A. A., & Vaidehi, V. (2011). An efficient face recognition system using DWT-ICA features. In *2011 International conference on digital image computing: techniques and applications* (pp. 146–151). IEEE.

25. Kämäräinen, J. K., Hadid, A., & Pietikäinen, M. (2011). Local representation of facial features. In: *Handbook of face recognition* (pp. 79–108). Springer.
26. Wagner, A., Wright, J., Ganesh, A., Zhou, Z., Mobahi, H., & Ma, Y. (2011). Toward a practical face recognition system: Robust alignment and illumination by sparse representation. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 34*(2), 372–386.
27. Satonkar Suhas, S., Kurhe Ajay, B., & Prakash Khanale, B. (2012). Face recognition using principal component analysis and linear discriminant analysis on the holistic approach in facial images database. *Int Organ Sci Res, 2*(12), 15–23.
28. Liao, S., Jain, A. K., & Li, S. Z. (2012). Partial face recognition: Alignment-free approach. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 35*(5), 1193–1205.
29. Han, H., Klare, B. F., Bonnen, K., & Jain, A. K. (2012). Matching composite sketches to face photos: A component-based approach. *IEEE Transactions on Information Forensics and Security, 8*(1), 191–204.
30. Belhumeur, P. N., Jacobs, D. W., Kriegman, D. J., & Kumar, N. (2013). Localising parts of faces using a consensus of exemplars. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 35*(12), 2930–2940.
31. Datta, D., Mishra, S., & Rajest, S. S. (2020). Quantification of tolerance limits of engineering system using uncertainty modeling for sustainable energy. *International Journal of Intelligent Networks, 1*(2020), 1–8. https://doi.org/10.1016/j.ijin.2020.05.006
32. Zhou, H., Mian, A., Wei, L., Creighton, D., Hossny, M., & Nahavandi, S. (2014). Recent advances on single modal and multimodal face recognition: a survey. *IEEE Transactions on Human-Machine Systems, 44*(6), 701–716.
33. Li, H., Lin, Z., Brandt, J., Shen, X., & Hua, G. (2014). Efficient boosted exemplar-based face detection. In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 1843–1850).
34. Posiyya, A., & Saikumar, K. (2020). Data management by a librarian for academic and research perceptions. *International Journal of Psychosocial Rehabilitation, 24*(8), 545–551.
35. Soumya, N., Kumar, K. S., Rao, K. R., Rooban, S., Kumar, P. S., & Kumar, G. N. S. (2019). 4-bit multiplier design using CMOS gates in electric VLSI. *International Journal of Recent Technology and Engineering (IJRTE).* ISSN 2277-3878.
36. Raju, K., Pilli, S. K., Kumar, G. S. S., Saikumar, K., & Jagan, B. O. L. (2019). Implementation of natural random forest machine learning methods on multispectral image compression. *Journal of Critical Reviews, 6*(5), 265–273.
37. Vijetha, A., Shashirekha, T., Raju, K., Rooban, S., & Saikumar, K. (2020). A robust fake currency detection model using ESVM machine learning technique. *Journal of Advanced Research in Dynamical and Control Systems, 12*(06), 170–179.
38. Saikumar, K., & Rajesh, V. (2020). Coronary blockage of the artery for heart diagnosis with DT artificial intelligence algorithm. *International Journal of Research in Pharmaceutical Sciences, 11*(1), 471–479.
39. Ding, C., & Tao, D. (2016). A comprehensive survey on pose-invariant face recognition. *ACM Transactions on Intelligent Systems and Technology (TIST), 7*(3), 1–42.
40. Al-asadi, T. A., & Obaid, A. J. (2016). Object Based Image Retrieval Using Enhanced SURF. *Asian Journal of Information Technology, 15*(16), 2756–2762.
41. Meshram, C., Ibrahim, R. W., Obaid, A. J., Meshram, S. G., Meshram, A., & Abd El-Latif, A. M. (2020) Fractional chaotic maps based short signature scheme under human-centered IoT environments. *Journal of Advanced Research.*
42. Obaid, A. J., Alghurabi, K. A., Albermany, S. A. K., & Sharma, S. (2021) Improving extreme learning machine accuracy utilizing genetic algorithm for intrusion detection purposes. In *Advances in intelligent systems and computing* (pp. 171–177). Springer.
43. Obaid, A.J. (2021). Critical research on the novel progressive, JOKER an opportunistic routing protocol technology for enhancing the network performance for multimedia communications. In *Research in intelligent and computing in engineering. Advances in intelligent systems and computing*, (vol. 1254, pp. 369–378). Springer.

44. Sharma, S., & Obaid, A. J. (2020). Mathematical modelling, analysis and design of fuzzy logic controller for the control of ventilation systems using MATLAB fuzzy logic toolbox. *Journal of Interdisciplinary Mathematics, 23*(4), 843–849.