FRS-OCC: Face Recognition System for Surveillance Based on Occlusion Invariant Technique

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Summary
Automated face recognition in a runtime environment is gaining more and more important in the fields of surveillance and urban security. This is a difficult task keeping in mind the constantly volatile image landscape with varying features and attributes. For a system to be beneficial in industrial settings, it is pertinent that its efficiency isn't compromised when running on roads, intersections, and busy streets. However, recognition in such uncontrolled circumstances is a major problem in real-life applications. In this paper, the main problem of face recognition in which full face is not visible (Occlusion). This is a common occurrence as any person can change his features by wearing a scarf, sunglass or by merely growing a mustache or beard. Such types of discrepancies in facial appearance are frequently stumbled upon in an uncontrolled circumstance and possibly will be a reason to the security systems which are based upon face recognition. These types of variations are very common in a real-life environment. It has been analyzed that it has been studied less in literature but now researchers have a major focus on this type of variation. Existing state-of-the-art techniques suffer from several limitations. Most significant amongst them are low level of usability and poor response time in case of any calamity. In this paper, an improved face recognition system is developed to solve the problem of occlusion known as FRS-OCC. To build the FRS-OCC system, the color and texture features are used and then an incremental learning algorithm (Learn++) to select more informative features. Afterward, the trained stack-based autoencoder (SAE) deep learning algorithm is used to recognize a human face. Overall, the FRS-OCC system is used to introduce such algorithms which enhance the response time to guarantee a benchmark quality of service in any situation. To test and evaluate the performance of the proposed FRS-OCC system, the AR face dataset is utilized. On average, the FRS-OCC system is outperformed and achieved SE of 98.82%, SP of 98.49%, AC of 98.76% and AUC of 0.9995 compared to other state-of-the-art methods. The obtained results indicate that the FRS-OCC system can be used in any surveillance application.

Key words: *Computer vision, Face Recognition, Local binary pattern, partial occlusion, Color space, Feature Extraction, Stack-based autoencoders*

1. Introduction

Automatic human activity recognition has strained much devotion of researchers nearby the globe because of its encouraging outcomes. Depending on the difficulty and period, human activities can be divided into four groups, i.e., gestures, actions, interactions, and group activities. Vision-based human activity recognition methodologies can be separated into two main groups.

- The customary handcrafted representation-centered method that is founded on the professional intended feature detectors and descriptors like Hessian matrix-based features SIFT, HOG, SURF, and LBP. Then, there is a common trainable classifier for action recognition.
- Learning-based representation method, that is a lately arose method with ability of learning features automatically from the raw data.

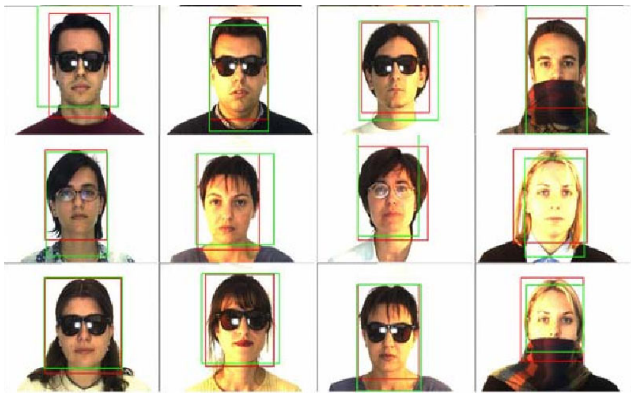


Figure 1. Sample Occluded Images from AR face dataset [10]

Figure 1 shows some sample images where the face is not visible. These images are taking from the AR face dataset [10]. In some cases, the mouth portion is not visible and is covered by a scarf while in some other cases, eyes portions are covered due to glasses. In some cases, eyes, and mouth both are covered by a scarf or glasses. Another example is visually represented in Fig.2, where all human faces are not visible due to crowd and occlusion. As a result, it is very difficult to recognize the human face. These are some different types of faces where it is very difficult to recognize due to partial occlusion. In this paper, an improved face recognition system is developed to solve the problem of occlusion known as the FRS-OCC system.

Manuscript received August 5, 2021
Manuscript revised August 20, 2021
https://doi.org/10.22937/IJCSNS.2021.21.8.38

Therefore, automatic face recognition is required that can solve such types of problems. In this paper, the FRS-OCC system has been proposed. It divides the face portion into different regions and assigns weights according to their importance and role for face recognition. Detail proposed method has been described in section 3.

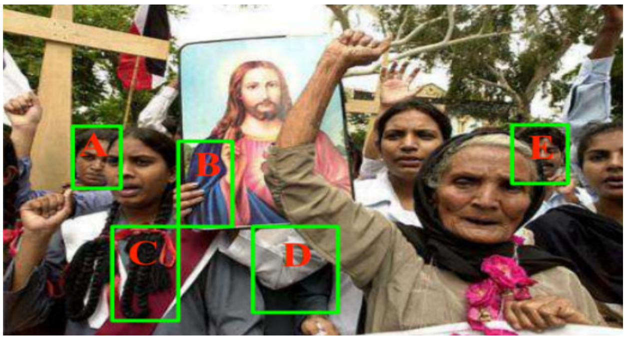


Figure 2. Occluded Face image samples in group of persons

The rest of the paper is organized as follows. Section 2 describes the related research papers about face recognition using the occlusion invariant technique. In section 3, the proposed FRS-OCC system for face recognition is detail described. Section 4 is presented the experimental setup and parameters selected for the recognition model. Whereas section 5 is described the discussions and conclusions of the paper.

2. Literature Review

The work proposed in this document can be broadly treated as an image processing application. The basic focus of this project is to analyze the security issues related to the facial parts of humans. It majorly focuses on information technology programs, especially on IT security. Although substantial development in face recognition research over the preceding decade [1]. But current existing face recognition schemes are not precise or vigorous adequate to be entirely set up in high-security environments. Several important applications dealing with critical problem areas such as medical, transportation, surveillance, and scientific research. However, there are still several limitations when it comes to real-world applications.

It believes that significant gains in recognition performance can be obtained by designing "specialized" face recognizers [2]. This can be achieved by developing systems that explicitly exploit important information from various visual cues (e.g., eyes, nose, lips, eyebrows, gender, ethnicity, age, etc.) for recognition purposes. Assigning faces to different face categories and employing “category-specific” recognition is equivalent to incorporating an adaptation mechanism to the recognition process which allows recognition to self-calibrate itself based on the type of faces to be recognized. This proposed project aspires [3] to advance the state of the art in face recognition by investigating this promising research direction. To achieve our goal, we plan to exploit novel learning algorithms, coupled with powerful feature selection strategies which can identify faces in a non-intrusive fashion even when encountered with partial occlusion. This proposed work can yield significant and promising research interests for both securities and face recognition domains. The proposed research will enhance the capabilities of existing face processing systems in various ways. The proposed work will not only recognize people from face images in the occluded environment but also extract important information such as eyes detection, lips detection, eyes and lips distance calculation, nose detection, eyebrows detection, and eyebrows distance as well as gender, ethnicity, and age.

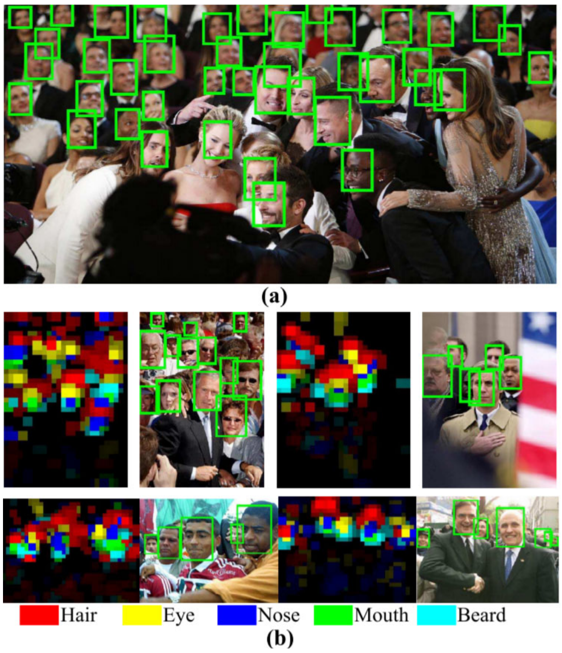


Figure 3: Example of crowd where different parts are occluded and visible

A face recognition system capable of yielding and utilizing all this information will be the critical capability of future face processing systems. A system performing robust classification based on the features mentioned above could provide a basis for passive surveillance and control. With the help of such a system, the authorities can collect valuable demographics-based information, and provide valuable consumer statistics in shopping centers or other public places. In brief, the possibilities of utilization of proposed work are immense for several applications domains. Another proposed application of our work is to investigate the application of 3D images for face recognition. 3D face recognition has important potential advantages over 2D as it makes use of shape and texture channels simultaneously. This will be an important investigation of our work. Figure 2 and Figure 3 have been taken from [28].

It is widely used in the areas of security video systems such as banking, district government surveillance, and transportation center or public places [1,2]. The thief usually covers their faces with headphones and sunglasses for the blind or hides their identity while committing a crime. Do not allow anyone to cover their faces to go into the safety zone. To reduce the risk of crime goes, an intelligent algorithm that can detect a person covering their faces in the field of security is essential. You need to monitor system performance efficiently and automatically in case of non - stationary

Background and when there are many people in the image. Overlapping detection algorithms faces are shown in the last decade [2-5]. However, current research does not effectively when changing background and there is more than one person in the picture. To improve the performance of existing research, it is important to study the restrictions on existing research before placing a new algorithm. The objective of this work is to provide an overview of ethics based on the detection of occluded faces; the focus is on the performance of the method of

Automation, and a variant of the objects used and people around the difference. Locate the menu for obstructing face detection using two types of data: still images and image sequences. Compared with a static image, and the image sequence contains articles for a static image, for example, detection of a moving object using images as the human sequence is more efficient than the use of a static image. It has been proposed various methods for detecting the occlusion of the face using a still image and the image sequence to date. Mr. Sang Y. and others. [5] use vector machines (SVM) for detecting the face of a person using ATM occluded (ATM). This method will not face covered with a mask or sunglasses. And the use of facial features and the regime's face superimposed normal training. By integrating principal component analysis (PCA) and SVM, and the revelation of his face is classified as normal, or toggle switches occluded. And precision is 95.5% and 98.8 % for the detection of sunglasses brands, respectively. Using SVM and are affected by the general characteristics of the face easily by noise or occlusion. K. Huta [6] solves this problem by applying SVM local jewels. Durability has been improved for obstruction. The Hota method is tested using sunglasses or a scarf. Coretta T. et al. [7] to improve Sustainability blockade on facial recognition and detection. It is proposed that the structure of the neural network, which combines automatic fixing of the neural network in the book is simple. Part of the face and hosted using sunglasses and rectangular. It should be noted the facial image of the original partial facial image covering. The region, occlusion is detected. Original face can be constructed by replacing reminders pixels that overlap.

Therefore, an integrated network may be highly rated covering the face. J. Kim et al. [4] based on the education proposal, for example, the approach for detecting a partially occluded facial image captured by a camera at an ATM of a bank. The use of a mask, sunglasses, and quiet was detected. SVM is used to classify the occluded side. Using this method, and the representation of the face of high-contrast lighting. J. Chen et al. [8] propose a method of detecting the occluded by other objects' faces. They have trained face detectors based on AdaBoost and function using Haar Category. The face area is divided into several patches. Fixed to each book's weaknesses. When checking the side of the room, then the threshold is determined. He decided that the threshold for establishing a stain face candidate with a different voting weight is if the window subentry is the face. S.D. And Saint Léon. [9] presents an algorithm for automatic detection of face wearing a helmet, mask, sunglasses, and a hat. This method was developed for monitoring the ATM. And it offers an image by a surveillance camera installed in almost all ATMs.

Several other researchers developed a face recognition system by using image processing and machine learning algorithms [11-28] to solve the problem of face occlusion. However, still there is a dire need to develop a robust face recognition system due to current COVID-19 situation, where most of the people are wearing big face masks. Moreover, the 75% of the face is hidden behind the facial masks. Also, the viewpoint, the application of research in real-world applications, and existing methods for automatically detecting the face-covering. Although a person's body range variety.

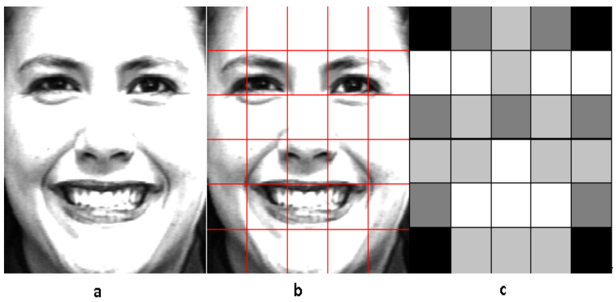


Figure 4: A face image divided into 6x5 sub-regions and assign different weights to different regions

3. Research Methodology

First, the FRS-OCC system is developed by taking an input image that is preprocessed to extract the face portion.

After that, that the face portion is divided into different parts for color and texture features extraction. Later these features are selected using incremental learning (Learn++). Later, the stack-based autoencoder (SAE) is deployed to recognize human faces by using the training process. The preprocessing step has been performed by using the well-known state-of-the-art method that is Voila Jones. It has been already proved that this method works well to extract face portions. After preprocessing, the face portion has been divided into different parts as shown in above figure 2. Next, the acquisition of dataset features extraction, and classification phases are explained in the subsequent paragraphs.

3.1 Acquisition of Dataset

Data is collected in two different ways. Before the development and deployment of the proposed technique, data will be collected offline from standard datasets available on the internet. Post-deployment data will be collected online using a live application installed at different places of security places. The data is collected for the same experiments as were conducted earlier and will be collected for the same quality attributes as were used for the offline data. This is done so that consistency and accuracy can be insured while reporting the results and making final recommendations. The approximate size of the installed application at different places is around 10 in experiments. After learning the material, subjects will be put into operation using principles of controlled experiments with constrained conditions. The experiments will be repeated after the deployment of the proposed technique under the same controlled constrained.

It proposes to investigate a novel approach to face recognition in a partially occluded environment especially in real-time data acquisition. The face recognition problem is divided into subproblems by using various visual cues and geometry like eyes, nose, eyebrows, chin, color, and gender. This is corresponding to the specific perceptual processes being employed by humans for face recognition in general. The proposed approach consists of two main steps. First, different portions of the face are extracted like eyes separation, eyebrows extraction, nose detection, nose shape and length, eyes distance calculation, lips detection, etc. Information from various visual geometry and cues (e.g., eyes, nose, lips, eyebrows, gender, and age) is used to calculate the occluded portion of the face part. Second, once the occluded portion of the face has been calculated, it is recognized using the remaining cues of the face part. Several challenges need to be addressed to design and implement the proposed approach. First, it needs to address the issue of what information to use to form the full face and remove the occluded portion. This step would require using information from various visual cues. It is considered both manually and automatically (through clustering) extracted facial cues. An intuitive way to categorize faces is using visual information based on eyes, lips, nose, gender, and age. Using additional cues, for example, based on face geometry (i.e., oval versus more rounded faces) is another possibility.

It decides to investigate ideas from experimental psychology as the first guide to this. Another possibility is to devise procedures to automate this process, thus, possibly discovering a more optimal face partition. For example, it could apply clustering to find a small number of prototypes in the face dataset. Then, it could partition the face space for each prototype using the nearest center approaches. Integral images will be also used for this purpose. In the second step, it determines to calculate which parts are occluded in the images. Then there is required to complete those parts by using integral imaging. It is also trying to recognize the faces by those parts which are not occluded. It tries to explore 3D imaging technology for occluded images. To test and compare the FRS-OCC system, it is used the most famous dataset AR face dataset.

3.2 Color and Texture Features Extraction

Features extraction is a key step in the development of face recognition with occlusion invariant property. In this paper, the FRS-OCC system is developed based on color and texture properties of a face image, which is divided into equal size windows. The properties of the feature set extracted have a significant impact on the performance of classification, and feature selection steps. The classification step is carried out based on this feature set combine with color and texture space in a perceptual-oriented color space. Each class's feature space should have some distinguishing properties that a classification system may learn and use to determine the class to which it belongs. If, on the other hand, feature overlapping occurs (1c. a feature set belonging to one class matches a feature set belonging to another class), a features selection and classification techniques are not provided accurate recognition results.

In this study, the digital color images are captured by a high-definition camera that contains face occlusion characteristics. Color properties played an essential part in the characterization of these faces since color information is quite crucial. The suggested system is also perfectly suited to human vision, owing to the use of the CIE L*a*b* color space, where L*represents brightness, a*represents the color's location between red/magenta and green, and b*represents yellow and blue in the same way.

The color characteristics are retrieved after converting the RGB picture to the CIEL*a*b* perceptual-oriented color space. Color features are utilized in a variety of image identification tasks, primarily because the color of an item or scene is frequently highly important in the image. Furthermore, as compared to other visual qualities, the image's color attributes are quite important. Color coherence, moments, and correlation characteristics are extracted from each image in the CIEL*a*b* perceptual-oriented color space in this paper.

To extract texture properties of a face image, local binary pattern (LBP) is simply employed. The LBP is selected in this paper because it can capture the diversity of face image even in case of occlusion. The LBP characteristics have been successfully employed in a variety of applications. Because LBP features are suitable for multi-resolution, grayscale, and rotation invariant texture encoding, it has been utilized them to describe the expression space. Furthermore, LBP characteristics are computationally efficient, simple to implement, and have lighting change tolerance. The LBP operator has been enhanced to consider various neighbor sizes. The operator provides 2P distinct output values for P adjacent pixels, corresponding to the 2P various binary patterns that can be created. Certain binary patterns have been demonstrated to hold more information than others. As a result, only a subset of the 2P LBPs may be used to represent textured pictures. These basic patterns are defined as having a minimal number of bitwise transitions from 0 to 1. To describe brief technique about LBP, consider an example, the 00000000 and 11111111 contain 0 transitions, while 00000110 and 01111110 contain 2 transitions and so on. Such patterns are called uniform patterns denoted by LBP^{2U}. A visual example of this LBP algorithm is explained in Fig.5.

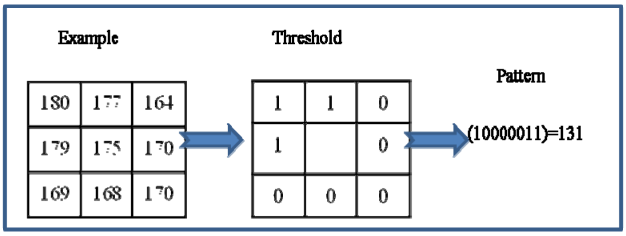


Figure 5. A visual example of LBP calculation to explain the pattern detection process

In this paper, the FRS-OCC system is developed based on color and texture features. To extract texture patters, the LBP technique is used on different partitions of face image. A visual example of LBP used in this study is presented in Fig.6. In practice, there are small regions presented in the image that are less contribute to the recognition of human face compared to other parts of the face image such as mouth and eye regions. As a result, the weighting scheme is introduced in this paper to the LBP original technique so that important parts of the face have higher weights compared to less important parts of the face block. For each image I(x,y), in each dataset d, the image is divided into {r x c = 6} weighted regions. The resulting image is denoted by I'(x,y). After labeling each block/region of an image with the LBP operator, a histogram of each labeled block $\Upsilon^{r,c}_{d,i}$ can be defined as:

$$h^{r,c}_{d,i}(\tau)=\sum_{x,y}\phi\left[\Upsilon^{r,c}_{d,i}(x,y)=\tau\right], \quad \tau=0,1,...,n-1 \tag{1}$$

Where n is the number of different LBP labels (59 for u2) and:

$$\phi(A)=\begin{cases}1, & if\ A\ is\ true\\ 0, & if\ A\ is\ false\end{cases} \tag{2}$$

Since we used extended local binary operator $LBP^{U2}_{8,2}$, a LBPH feature vector of [1x69] is calculated for each region [r, c]. Then these LBPHs are concatenated and normalized to get the final LBPH representation for each image. This set of histograms represents the texture information of local regions and global shape information due to the concatenation of local histograms.

$$H_{d,i}=Norm\left([h^{r,c}_{d,i}]^{r=6,c=5}_{r=1,c=1}\right) \tag{3}$$

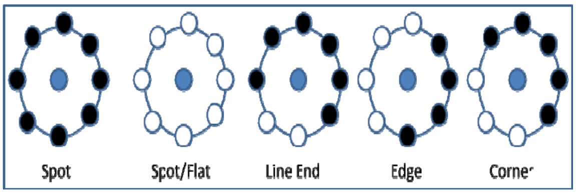


Figure 6. Examples of texture primitives

Lastly, all the texture and colour features are combined into a single feature vector. Remember that the colour features are extracted in the perceptual-oriented colour space. It observed by experiments that the data in the combine features vector is not normalized. To make it normalize, the range of values between 0 and 1 by dividing each element by its norm, which is the square root of the sum of the squares of each element.

3.3 Features Selection

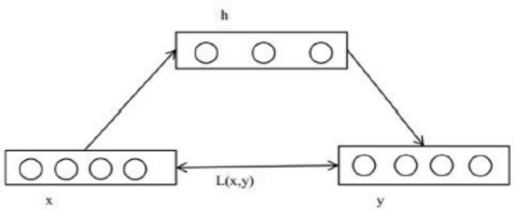
The features selection step is very important for the accurate detected of most informative features because it is the only step that is contributed towards the solution of problem of face occlusion. To solve the problem face occlusion, the incremental learning Learn++ [24] algorithm is used in this paper to detect features in an incremental fashion. The main beauty of this technique is to selected features in an iterative manner and minimize training errors in each iteration. Accordingly, the Learn ++ algorithm is very strong to detect strong occlusion in the features set and select most informative features.

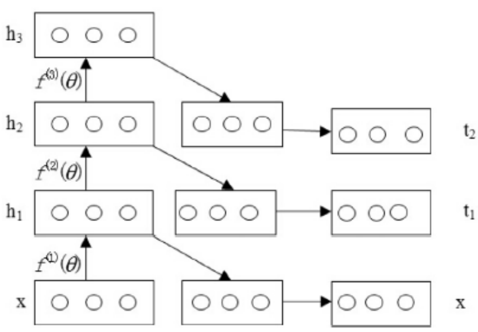
To detect distinguish characteristics of features, the Learn++ [24] machine learning method is used. The Learn++ classifier is built by first building week classifiers and then merging them using the majority vote method to reach a final choice. In practice, the Learned algorithm may learn new data by changing the distribution of the training dataset whenever a new dataset becomes available. It differs from previous multi-class classifiers due to the intelligent distribution of the training dataset. As a result, for the purpose of learning characteristics. Finally, a distinct features set is formed by using algorithm and submitted to face recognition phase.

3.4 Face Recognition

The Stacked auto-encoder (SAE) is used in this paper to recognize the human face in case of occlusion. This is type of deep-learning model and it provided best result in case of face occlusion. Therefore, the SAE is selected to build the FRS-OCC system. This deep learning based model is shortly described in the upcoming paragraphs.

By stacking several auto-encoders, the most popular feed-forward neural networks are utilized to create a stacked auto-encoder model. [21][22]. A basic self-encoder has two stages: the encoding function (shown in fig. 7) and the decoding function, which is generally a non-linear function of mapping. The four most popular non-linear activation functions are the Sigmoid function, tanh function, soft sign function, and ReLu function.





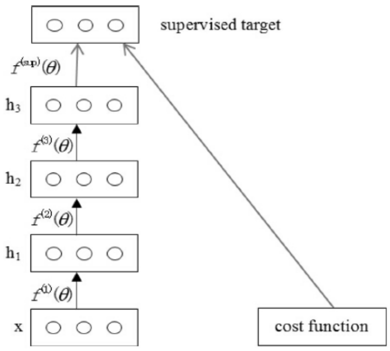


Figure 7. A visual example of LBP calculation to explain the pattern detection process

The fundamental autoencoder parameters are obviously learned using an unsupervised approach. The hidden layer h is made up of the extracted attribute or hidden image of the input data x. If h is smaller than x, the basic autoencoder can be understood as a compression method. The basic auto-encoder model has numerous variations. Another typical version is the sparse auto-encoder [24],[25]. The autoencoder usually has a sparse hidden representation if the p-value is near to 0. A deep learning model called a stacked autoencoder may be created using many autoencoders to learn hierarchical features or representations for the input, as illustrated in Fig 7.

The stacking auto-encoder is usually learned in two phases. During the pre-training step, an unsupervised layer is used to train the autoencoder model from bottom to top. The Auto-encoder receives the input h0 = X and outputs Y0 for training the first hidden layer parameters, followed by h1 for training the second hidden layer parameters. It's an iterative procedure that continues until all the unseen layer's parameters have been learned. The parameters are then set to the auto-encoding stacked's starting values. In the fine-tuning stage, specific samples are utilized as supervised entities to fine-tune parameters from top to bottom, as shown in Fig7.

4. Experimental Results

The proposed face recognition system with occlusion invariant (FRS-OCC) property is evaluated and trained on mainly AR face dataset and implemented in Python on a Computer ThinkPad Core ™ i7-6578 CPU with 2.7 GHZ, 16 GM of RAM running Microsoft Windows 10, 64-bit operating system. All images are preprocessed by using voila jones method and then this extracted part are selected and stored in a database before feature extraction step. In this paper, the features selection step is performed by using Learn++ machine learning algorithm and the classification decision is performed using stack-based autoencoder (SAE). In the training dataset, the 30% of face images are divided as to train the SAE classifier and 70% of images are used to test the recognition of FRS-OCC system.

Table 1. Experimental results of the proposed FRS-OCC system compared to state-of-the-art machine-learning algorithms in terms of Accuracy (AC), Sensitivity (SE), Specificity (SP) and area under the receiver operating curve (AUC) measures.

Classifier	Features	AC	SE	SP	AUC
SVM	Color	93.25	87.26	91.46	0.9738
	Texture	94.89	90.49	92.35	0.9729
	Combined	95.26	94.31	92.85	0.9819
KNN	Color	87.17	88.55	91.85	0.9771
	Texture	88.26	90.23	92.89	0.9778
	Combined	93.43	95.77	92.97	0.9816
Decision trees	Color	90.46	87.78t	92.04	0.9486
	Texture	92.27	89.29	92.89	0.9591
	Combined	93.16	93.41	93.39	0.9597
ANN	Color	95.29	94.76	94.69	0.9704
	Texture	96.43	94.19	96.45	0.9863
	Combined	97.57	95.35	96.79	0.9896
FRS-OCC	Color	97.91	95.32	96.98	0.9839
	Texture	97.86	96.44	97.76	0.9889
	Combined	**98.82**	**98.49**	**98.76**	**0.9995**

To measures the performances and comparisons of proposed FRS-OCC system, the Sensitivity (SN), Specificity (SP) and area under the curve (AUC) statistical matrices are measured from the dataset. On the test data set, the area (AUC) under the receiver operating characteristic analysis is utilized to analyze the sensitivity (SE) and specificity (SP). The area under the curve (AUC) is a widely used metric for evaluating overall discrimination. The AUC spans from 0.50 to 1.0, with the higher the number, the recognition system got higher accuracy in case of face occlusion. It is mentioned before that the data set is split into training (30%) and testing (10%) for experimental analysis (70%). The overall average outcomes of the suggested system are shown in Table 1.

In literature, many ensemble classifiers are utilized. These classifiers were supposed to provide strong classification results based on ensemble of weak classifiers through a procedure called boosting. Using a majority voting technique, these weak classifiers are combined, which are provided better performance compared to other strong classifiers. Moreover, other strong classifiers such as AdaBoost are also suffered overtraining compared to Learn++ algorithm because it is designed to add incremental learning capability to an existing classifier. As a result, it is the beset candidate used to detect effective features from the large features set.

After normalization of each feature, the features selection and matching steps are performed through Learn++ and SAE algorithms, respectively in this proposed system. This Learn++ algorithm has selected randomly training dataset, weak learners, and an integer parameter with value of 12, specifying the number of classifiers to be generated. In this setup of Learn++ algorithm, neural networks are selected because these are most suitable weak learners, in which layers and/or classification errors are used to control their weakness. In the decision step, top-most n-ranked images are selected by using majority voting, which are matched with the query image. In fact, n-ranked images are selected with highest votes compared to the features of query image. The majority voting mechanism effectively fine-tunes the classification decision from the rough estimates provided by each classifier.

Figure 8. A visual example of Face occlusion masks during current COVID-19 situation

The proposed system is effective for recognition of faces even in case of face occlusion. This information is captured on COVID-19 face occlusion dataset as shown in Fig. 8. Compared to other machine learning algorithms, the proposed FRS-OCC is outperformed in case of COVID-19 face mask to recognize human faces. The results of the proposed system are shown in Table 1. Table 1 demonstrates that sensitivity, specificity, and area under the curve analysis are greatly improved by extracting informative features. Furthermore, the average value of AUC i.e., 0.97 has been improved as compared to state-of-the-art systems. This is the reason due to which it shows good classification results.

5. Conclusions

The current system FRS-OCC in the field of computational intelligence ensure that it is possible to develop such a system which handles these intractable problems while ensuring efficiency and optimization. It observed that the inclusion of all these fundamentally vital concepts help in evolution of one such technique which is highly perceptible and can recognize faces despite partial occlusions as proof by COVID-19 face mask dataset. The proposed FRS-OCC system research is aimed at investigating, analyzing, and developing algorithms to implement these techniques. It has been analyzed that it has been studied less in literature but now researchers have a major focus on this type of variation. Existing state-of-the-art techniques suffer from several limitations. Most significant amongst them are low level of usability and poor response time in case of any calamity. In this paper, an improved face recognition system is developed to solve the problem of occlusion known as FRS-OCC. To build the FRS-OCC system, the color and texture features are used and then an incremental learning algorithm (Learn++) to select more informative features. Afterward, the trained stack-based autoencoder (SAE) deep learning algorithm is used to recognize a human face. Overall, the FRS-OCC system is used to introduce such algorithms which enhance the response time to guarantee a benchmark quality of service in any situation. The obtained results indicate that the FRS-OCC system can be used in any surveillance application.

Acknowledgments

The author would like to express their cordial thanks to the deanship of scientific research at Imam Mohammad Ibn Saud Islamic University (IMSIU), Riyadh, Saudi Arabia.

References

[1] M. Martinez, “Recognizing Imprecisely Localized, Partially Occluded and Expression Variant Faces from a Single Sample per Class”, in IEEE Trans. on PAMI, V.24, p748-763, 2002
[2] P. Quintiliano, A. N. Santa-Rosa, R. Guadagnin “Face recognition based on eigenfeatures”, Proc. SPIE Vol. 4550, p. 140-145, Image Extraction, Segmentation, and Recognition, 2001
[3] M. A. Turk, A. P. Pentland, “Face recognition using eigenfaces”, Proceedings of the IEEE Computer Society Conf. on Computer Vision and Pattern Recognition, pp. 586-591, Hawaii 1991.
[4] J. Kim, Y. Sung, S.M. Yoon and B.G. Park, “A New Video Surveillance System Employing Occluded Face Detection”, Proc. of the 18th int. conf. on Innovations in Applied Artificial Intelligence, Italy, pp. 65-68, 2005.
[5] S. M. Yoon and S. C. Kee, “Detection of Partially Occluded Face using Support Vector Machines”, IAPR Workshop on Machine Vision Applications, Japan, pp. 546-549, 2002.
[6] K. Hotta, “A Robust Face Detector Under Partial Occlusion”, Int. Conf. on Image Processing, 2004 (ICIP '04), pp. 597-600, 2004.
[7] T. Kurita, M. Pic and T. Takahashi, “Recognition and Detection of Occluded Faces by a Neural Network Classifier with Recursive Data Reconstruction”, Proc. of the IEEE Conf. on Advanced Video and Signal Based Surveillance (AVSS’03), pp. 53-58, 2003.
[8] M. A. Mottaleb and A. Elgammal. Face Detection in complex environments from color images. IEEE ICIP: 622-626, 1999.
[9] J. Ross and Beveridge et. al. A nonparametric statistical comparison of principal component and linear discriminant subspaces for face recognition. Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition: 535 – 542, 2001.
[10] A.M. Martinez and R. Benavente, “The AR Face Database”, CVC Technical Report 24, 1998.
[11] A.M. Martinez, “Recognition of Partially Occluded and/or Imprecisely Localized Faces using a Probabilistic Approach”, CVPR, Vol. 1, pp. 712-717, 2000. MIT face database, ftp://whitechapel.media.mit.edu/pub/images/
[12] A.S. Georghiades, P.N. Belhumeur, and D.J. Kriegman, “From few to many: Illumination cone models for recognition under variable lighting and pose”, IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 23, no.6, pp. 643-660, 2001
[13] Abate A., Nappi M., Riccio D., and Tucci M., “Occluded Face Recognition by Means of the IFS,” in Proceedings of the 2nd International Conference Image Analysis and Recognition, Berlin, pp. 1073-1080, 2005.
[14] Aleix M., “Recognizing Imprecisely Localized, Partially Occluded, and Expression Variant Faces from a Single Sample Per Class,” IEEE Transaction on Pattern Analysis and Machine Intelligence, vol. 24, no. 6, pp. 748-763, 2002.
[15] Amirhosein N., Esam A., and Majid A., “Illumination Invariant Feature Extraction and Mutual-Information-Based Local Matching for Face Recognition under Illumination Variation and Occlusion,” Pattern Recognition, vol. 44, no. 10-11, pp. 2576-2587, 2011.
[16] Baudat G. and Anouar F., “Generalized Discriminant Analysis using a Kernel Approach,” Neural Computation, vol. 12, no. 10, pp. 2385-2404, 2000.
[17] Sharma, M., Prakash, S., & Gupta, P. (2013). An efficient partial occluded face recognition system. Neurocomputing, 116, 231-241.
[18] Li, X. X., Dai, D. Q., Zhang, X. F., & Ren, C. X. (2013). Structured sparse error coding for face recognition with occlusion. IEEE transactions on image processing, 22(5), 1889-1900.
[19] Ou, W., You, X., Tao, D., Zhang, P., Tang, Y., & Zhu, Z. (2014). Robust face recognition via occlusion dictionary learning. Pattern Recognition, 47(4), 1559-1572.

[20] Chen W., Yuen P., Huang J., and Dai D., “Kernel Machine-Based One-Parameter Regularized Fisher Discriminant Method for Face Recognition,” IEEE Transactions on Systems, Man, and Cybernetics, Part B: Cybernetics, vol. 35, no. 4, pp. 659-669, 2005.
[21] Yu, Y. F., Dai, D. Q., Ren, C. X., & Huang, K. K. (2017). Discriminative multi-scale sparse coding for single-sample face recognition with occlusion. Pattern Recognition, 66, 302-312.
[22] Wu, C. Y., & Ding, J. J. (2018). Occluded face recognition using low-rank regression with generalized gradient direction. Pattern Recognition, 80, 256-268.
[23] Long, Y., Zhu, F., Shao, L., & Han, J. (2018). Face recognition with a small occluded training set using spatial and statistical pooling. Information Sciences, 430, 634-644.
[24] Zheng, W., Gou, C., & Wang, F. Y. (2020). A novel approach inspired by optic nerve characteristics for few-shot occluded face recognition. Neurocomputing, 376, 25-41.
[25] Kumar, S., & Singh, S. K. (2020). Occluded Thermal Face Recognition Using Bag of CNN ($ Bo $ CNN). IEEE Signal Processing Letters, 27, 975-979.
[26] Qiu, H., Gong, D., Li, Z., Liu, W., & Tao, D. (2021). End2End Occluded Face Recognition by Masking Corrupted Features. IEEE Transactions on Pattern Analysis and Machine Intelligence.
[27] Bommidi, K., & Sundaramurthy, S. (2021). A compressed string matching algorithm for face recognition with partial occlusion. Multimedia Systems, 27(2), 191-203.
[28] Koc, M. (2021). A novel partition selection method for modular face recognition approaches on occlusion problem. Machine Vision and Applications, 32(1), 1-11.

Qaisar Abbasr research interests include such as image processing, medical image analysis and deep learning algorithms.