# Optimized Principal Component Analysis Algorithm Based Facial Recognition System with Liveness Detection for IoT Applications

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***Abstract*— Driven by commercial applications and daily basis security requirements, research, and analysis on facial recognition algorithms from video sources has become an area of growing interest among the researchers in recent times. In this paper, an algorithm is proposed based on facial recognition system incorporated with liveness detection that employs Principal Component Analysis (PCA) to extract and reduce the dimensions of the facial features and Support Vector Machine (SVM) is utilized to train these features to assure the physical presence of a person being detected. The system requires a real time video feed through which it extracts an individual frame that contains a detected face of a person using Viola Jones algorithm. Facial recognition process is followed by an eye blinking algorithm through which the system will identity the actual presence of a person on secure environment. The main objective of the proposed algorithm is to provide secure access to the authorized person and upload the information regarding his activity on the cloud server. Thus, the proposed system can be used to reduce the manual work involved in terms of operation and at the same time increase its efficiency. The overall efficiency of facial recognition system was found to be 90.72% and the face liveness was found to be 94.07% for the dataset used.**

***Keywords*— Principal component analysis (PCA), Facial Recognition, Viola Jones Algorithm, Face liveness Detection, Support Vector Machine (SVM).**

## INTRODUCTION

Operating a mall requires a lot of manual works and to track the entrance and exits of the employees and marking their attendance based on that is a tedious task. In this regard, facial recognition algorithm can be utilized to cater this task efficiently. Face recognition is a biometric method used extensively in commercial applications. It is an important biometric application in security access and surveillance systems [1]. The technique of biometric facial recognition is considerably used in the industry due to its non-invasive nature [2], such techniques are ideal for perceiving a person biometrically when he is unaware of being scanned, and it becomes much easier to identify him. Due to the angle of a person face, lighting conditions and even makeup variations are the key culprits through which facial recognition process suffers from poor identification and accuracy reduces dramatically in such situations [3]. There are many techniques used to implement face recognition system. Some of the techniques involve is a hybrid-skin color-eigen face detection method to develop a real-time face recognition application model for smart phones [4]. Hahn moments is also utilized to describe the features of the faces and apply it with facial recognition [5]. Hahn moments can be incorporated with block representation for faster face detection [6]. Both 2D and 3D image processing and facial detection can be performed using Hahn moments [7].

Difference of Gaussian (DoG) oriented facial recognition model also uses histogram to detect faces from the video stream, it became popular among the researchers because it uses histogram through which, the features can be easily extracted [8-12]. A face recognition system is presented in which Gray Level Co-occurrence matrix (GLCM) and Local Binary Pattern (LBP) are used for feature extraction and then these features are fused. The extracted features are classified using K-Nearest Neighbor (KNN) and support vector machines (SVM) classifiers and the optimization process is done by Particle Swarm Optimization [13-14 ]. Linear Binary pattern Histogram (LPBH) is another method of facial recognition that utilizes histogram, and it is widely used among the research community for the applications involving facial recognition [15-17]. An attendance system is also proposed based on LBPH face recognizer by Shanthi, S., et al [18]. LBPH is also used by the research community to extract facial features and implement the classical Machine learning algorithms such as K-nearest neighbor (KNN), Support Vector Machine (SVM), Naïve-Bayes Algorithm etc. [19-21]. In other techniques [22], an attempt has been made to identify similar looking individuals or identical twins by face recognition algorithms. Seven distinctive face acknowledgment calculations were utilized to check the execution of an examination in which an informational index comprised of 17486 pictures from 126 sets of indistinguishable twins assembled around the same time and 6864 pictures

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from 120 sets of indistinguishable twins gathered a year later were estimated [23]. In another paper, a profound survey on as of late exhibited strategies for defeating the issues experienced in uncontrolled settings in confront acknowledgment from video is introduced in. Manners by which people and late calculations perceive faces are additionally associated. To supplement these exchanges a review of the most famous and troublesome openly accessible face video databases is given [24]. A method to extract the hidden features to avoid the lighting conditions which makes face recognition difficult is presented in [25-26]. An authors proposed in [27] the challenge faced by automatic face recognition system due to facial aging which needs to come up with a matching scheme that is vigorous to changes due to aging of face which disturbs both the 3D shape of the face and the texture which comprises of wrinkles. To oversee diverse posture varieties in multi camera organize and perceiving faces from those recordings a strategy is planned to utilize Spherical Harmonic (SH) portrayal of the face [28].

The factor considered in this paper is the automate the security system to make it a more secure and safe place, and at the same time reduce the manpower required to operate it. There are enormous crime prevention techniques that can be implemented to improve and advance the security system not only in shopping malls but also in offices, hospitals, schools, universities, homes, and apartments. Innovation of technology is one of the greatest sources which is utilized to assure the progress and success of advance secure access systems through face recognition. The basic idea behind this paper is to design a real-time face recognition system for automated surveillance and security purpose in the malls. The proposed system is robust is a way that it cannot be fooled or hacked by a picture or a photo to mark the employee as present because, apart from facial recognition it also checks face liveness through eye-blinking which will assure the physical presence of the person.

## SYSTEM MODEL

The overall system in the proposed model is comprised of four main stages as displayed in Figure.1. Implemented camera will acquire a frame from a real time video stream for processing. That frame is passed through the process of face detection and tracking performed using Kanade-Lucas-Tomasi (KLT) [29-32] and Viola Jones [33] algorithms respectively, this is the first stage of the proposed model. It is a suitable process for the identification of a specific person with unique gestures, distinct features, and facial expressions [34]. By implementing Viola Jones and KLT algorithm, it is possible for identify a face accurately and at relatively high speed [35]. In the second stage, the frame containing a detected face is passed through the process of facial recognition, which is performed using PCA to extract facial features, and reduce the dimensionality before feeding it to Support Vector Machine (SVM) based classifier. After training the desired dataset, it is now able to identify the person present in the frame. The third stage of the process is linked closely with the third stage because if the person is recognized in the frame only then an employee is asked for his or her physical presence by prompting him to blink his eyes about three times, this process of liveness detecting is performed using OpenCV library on python platform. The fourth and final stage of the process is to upload the information about the physical presence of the person to the servers where that information can be utilized for future references if needed.

## FACE DETECTION AND TRACKING

For face detection, the proposed system will acquire individual frames from the live video stream running at 30 Frames Per Second (FPS) rate. To detect faces, a Cascade object detector is used which is a pre-trained classifier for frontal face detect from the acquired frame. Basically, it is a feature present in Viola jones technique in which multiple filters or kernels are used to pinpoint the position of eyes, nose, lips, etc. on a person’s face and where it lies in the frame [39]. These filters aid an algorithm to find the face within the frame and uses eyes, mouth, cheeks, and nose as features of a face. Moreover, it is possible to train the classifier to detect a person who is not facing the camera at a correct angle and even if he is wearing eyeglasses.

Viola Jones algorithm uses an examining box for sliding window in an image to match and coordinate different dark and light regions for face identification. Sliding window determines the presence of the face in the acquired frame on the bases of feature evaluation directly on the region bounded by the sliding window. Negative window, which denotes the absence of face are filtered out by the constructed algorithm of cascade classifier after inspection. When the negative window is filtered out, it slides the window to again in hopes of finding a face in the present window, the process is displayed in figure.2. The sliding window follows a zig-zag pattern to visit all the combination possible to detect facial features. The process of face detection using Viola Jones Algorithm is displayed in figure.3.

Sliding window searches specific facial feature using filters and if it identifies any of the feature like eyes, nose, etc. it saves the feature location and slide the window to find more features closely bounded to the previous detected feature. The whole process is repeated until it finds all the facial features closely bounded together to form a face, and when the face is detected in the present frame, the algorithm will identify it and place a bounding box on its location in the frame as displayed in figure.4. It can also detect multiple faces within the frame and thus place bounding boxes to identify them.
When the face is detected, the acquired image undergoes further processing to track the face using Kanade-Lucas-Tomasi (KLT) algorithm [29]. It tracks the face in two steps,

first it detects features points on the face and for the second part, it tracks those detected features as displayed in figure.5. The algorithm detects the features from past frame fn-1 attempts to identify the corresponding features in the current frame fn. The tracking algorithm utilizes estimation to translate the features between the consecutive frames. D represents the displacement between the points between the frames. Eq (1-3) represent the feature movement with affine transformation At. I represent the pixel of the current frame. Each iterative process requires individual frame features to track the movement of an object within the consecutive frames. A duplicate of the points is made for registering the geometric changes between the focuses in the past and current frames. From figure.5, the movement of the face will reduce the features tracked and if 2 or more points are

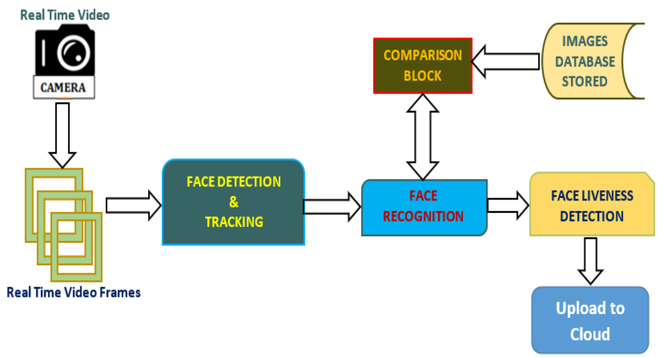


Figure 1 Block Representation of the Proposed Model

present or detected in the frame, the algorithm will keep tracking the detected face.

$$f_{n-1}(I) = f_n(At * I + D) \qquad (1)$$

$$At = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \qquad (2)$$

$$D = \begin{bmatrix} d_1 \\ d_2 \end{bmatrix} \qquad (3)$$

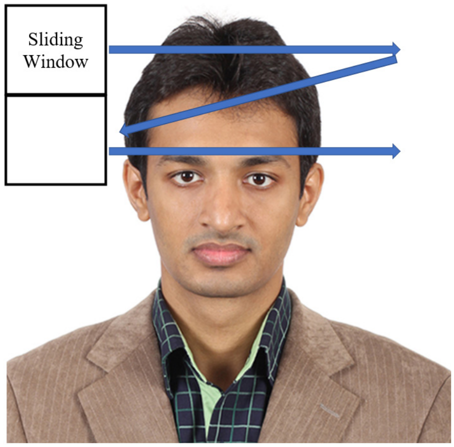


Figure 2 Sliding Window Searching for Facial Features

## DIMENTONALITY REDUCTION USING PRINCIPAL COMPONENT ANALYSIS (PCA) AND LIVENESS DETECTON

The process of facial recognition in real time is a fundamental part of the proposed system. It is performed using PCA algorithm on the acquired dataset of the employees, sample images of dataset used of 4 different people for the system are given in fig. 6. The image dataset is resized to have the resolution of 64×64 to retain most of its information and if the resolution is further reduced then the image loses its authenticity which may corrupt the dataset. 64×64 resolution will produce the total of 4096 features. The purpose of using PCA is to reduce the dimensionality of the acquired dataset with 4096 features, by transforming these large features dataset to comparatively smaller ones while retaining most of its valuable information.

Dimensionality reduction will reduce the number of dataset variables but at an expense of its accuracy. It is a tradeoff between the dataset complexity for simplicity. Reduce dataset is much more reliably, easy to use and explore, and the analysis of its information for algorithm based on machine learning is faster and easier without extensive variables to process. A Red Green Blue (RGB) Image dataset is transformed into grayscale format and the information of each image in the dataset is standardized before computing the covariance matric. Eq (4) represent the standardization of an image information, where p_x is a feature that needs to standardize, μ is mean of the feature vector, σ is the standard deviation.

$$S_x = \frac{p_x - \mu}{\sigma} \qquad (4)$$

When the feature vector is standardized, then the covariance matrix is calculated. Through covariance matrix, it is easy to understand the varying nature of an inputted dataset from

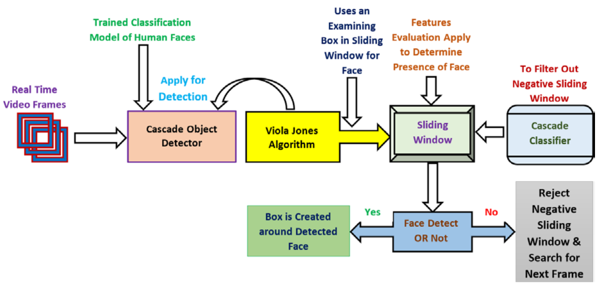


Figure 3 Face Detection Process using Viola Jones Algorithm Block Representation

each other if compared with its mean parameter μ. In some cases, these features have a high enough correlation, which may render the acquired information redundant, and the covariance matrix is utilized to remove this redundancy. Eq (5) represents the covariance matrix of the feature dataset. x and y are the dimension of the features. Eigen Values and Vectors are calculated to recognize the variance between the principal components that would distinguish between the classes on the bases of these variations. Principal component produces linear combination of initial feature variables, and all their associated combinations are uncorrelated.

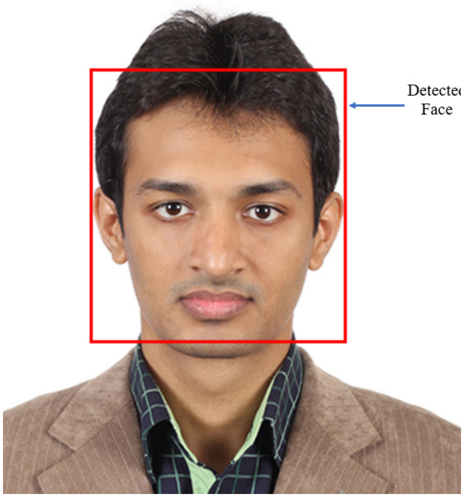


Figure 4 Face Detected with Viola Jones Algorithm

$$Cov(x,y) = \frac{1}{N-1} \sum_{n=1}^{N} \left(s_{xn} - \mu_{s_x}\right) \left(s_{yn} - \mu_{s_y}\right)^T \quad \text{-----(5)}$$

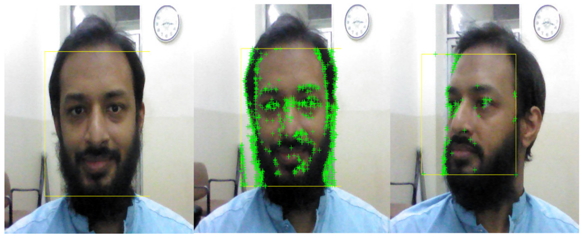

Figure 5 Left: Face detection, Center: Feature Detection, Right: Feature Tracking

Almost all the important information is compressed in the initial components to maximize the probably of positive outcome, rest of the principal component are not necessary and thus they can be neglected or dropped with minimum error or maximum accuracy. Selection of the Principal components that hold the variance information is performed using the graphs displayed in figure. 7 and figure. 8 respectively. It is evident that most of the principal components that have maximum variance are bounded close to origin given in figure. 7 and an appropriate principal component that needs to be selected must provide maximum accuracy. For the proposed system 40 principal components are selected to get the maximum accuracy possible. This can be verified from figure. 8. Out of 4096 components, only 50 of them are displayed in figure.7. The steps involved in the process of PCA is given in figure. 9.

Figure 6 Sample Image Dataset of 4 people

When the system recognizes a person in the acquired frame, then it will check for his physical presence by asking him to blink his eyes three times. Haar cascade classifier is employed in the proposed system to recognize facial components such as eyes and extract them. Since the person in the frame was asked to blink his eyes three times, when he closes the eyes, Haar classifier will not be able to detect the eyes until they are closed. Algorithm will register this as a single blink and the process is repeated three times.

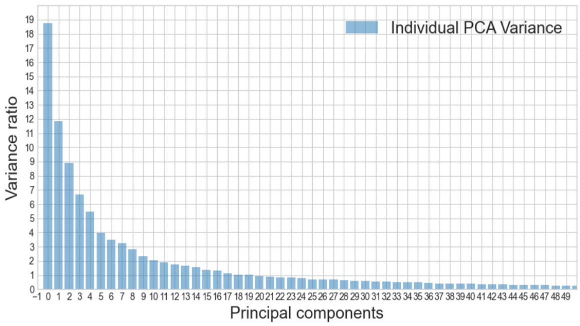


Figure 7 Principal Components Selection

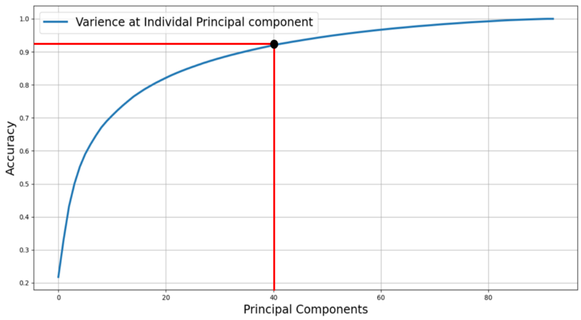


Figure 8 Accuracy Vs. Selected Principal Components Selection

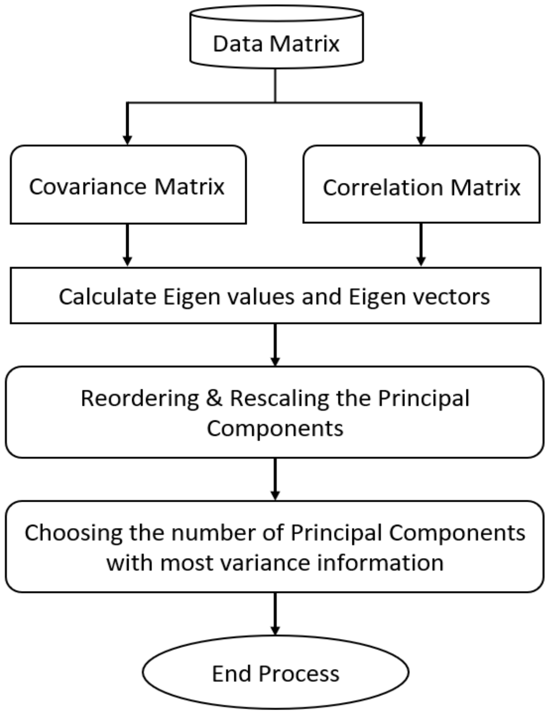


Figure 9 Steps to Choose best Principal components

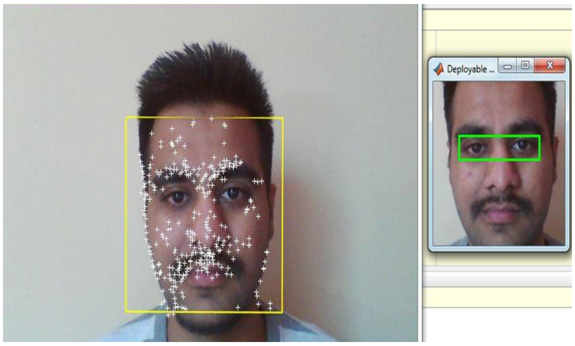

Figure 10 Liveness Detection with Haar Cascade Classifier

SVM is used to train the facial dataset after dimensionality reduction performed by PCA. SVM employs hyperplanes to distinguish between the classes. They are the points derived from the acquired data and located closed to the hyperplane and shape the orientation and placement of the hyperplane. Basically, the true intent of SVM is to obtain the maximum separating margin between the hyperplane of the trained dataset [36]. Figure. 10 represents the sample feature plane of two classes and the hyper plane separation between them with margin [37]. Hyper plane always follows the trajectory of Optimal Hyper plane. Eq (6-8) denotes the extension of the hyper plane if the weighted vectors are greater than 1, then it belongs to class. 1 and if not, then they belong to Class. 2. For the proposed model, it is not possible to plot the features on the plane due to the reason that 40 features were used for classification.

$$w^T x_q + b = \begin{bmatrix} +1 \\ 0 \\ -1 \end{bmatrix} \qquad (6)$$

$$w^T x_q + b > 1, \forall x \; to \; Class.1 \qquad (7)$$
$$w^T x_q + b < 1, \forall x \; to \; Class.2 \qquad (8)$$

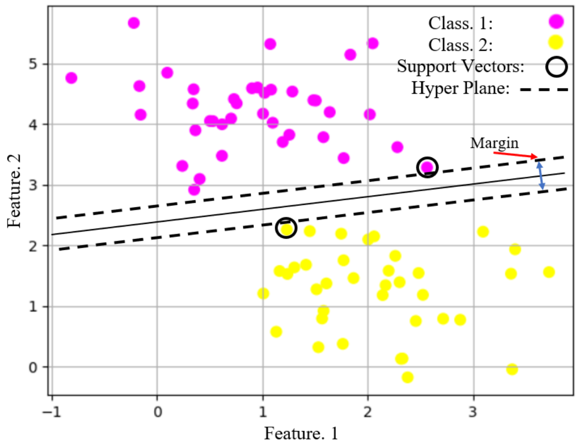


Figure 11 Support Vector Machine feature selection

## RESULTS

Table. 1 represents the list of the dataset for four people used in the system. All four datasets are denoted with their appropriate labels.

## CONCLUSION

Table 1 Image dataset of individual person with class

| S. No. | Labels | Name |
|---|---|---|
| 1 | 0 | Adeel |
| 2 | 1 | Taha |
| 3 | 2 | Ali |
| 4 | 3 | Sidra |

Table 2 Accuracy Parameters for SVM (Sample Set A)

| Labels | Precision | Recall | f1-score | Support |
|---|---|---|---|---|
| 0 | 1.00 | 1.00 | 1.00 | 7 |
| 1 | 0.78 | 0.88 | 0.82 | 8 |
| 2 | 0.88 | 0.78 | 0.82 | 9 |
| 3 | 1.00 | 1.00 | 1.00 | 8 |

Table 3 Confusion Matrix of SVM (Sample Set A)

| | | Predicted Class | | | |
|---|---|---|---|---|---|
| | | Adeel | Taha | Ali | Sidra |
| True Class | Adeel | 7 | 0 | 0 | 0 |
| | Taha | 0 | 7 | 1 | 0 |
| | Ali | 0 | 2 | 7 | 0 |
| | Sidra | 0 | 0 | 0 | 8 |

Table 4 Algorithm Efficiency

| Objective | Technique | Efficiency (%) |
|---|---|---|
| | | |
| Face Detection | Viola-Jones | 92.1 |
| Face Tracking | KLT | 89.6 |
| Face Recognition | PCA & SVM | 90.72 |
| Face Liveness Detection | Haar Cascade Classifier | 94.07 |

Facial Recognition process incorporated with Liveness Detection is an important Biometric technique that will revolutionize the security systems based on IoT applications. In this paper, a comprehensive algorithm is proposed which is a blend of facial recognition and liveness detection technique which can be implemented effectively for shopping malls, homes, educational institutes, offices, ATM's, identifying duplicate for voters, passport, and visa verification, driving license verification, defense etc. as a security system or for other purpose like attendance system.

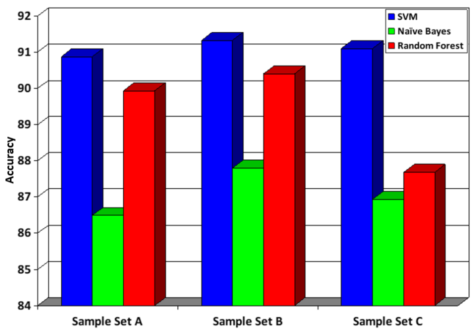


Figure 12 Accuracy comparison SVM, Naïve Bayes and Random Forest

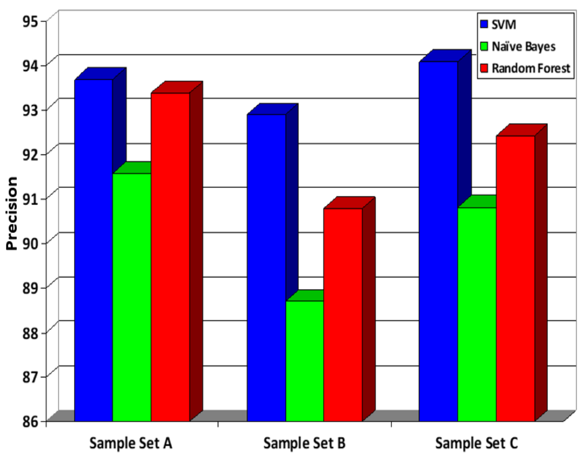


Figure 13 Precision comparison SVM, Naïve Bayes and Random Forest

Importantly, this automated system is robust and minimal human effort is required. The proposed algorithm has the capability to increase the number of users that have access the secure systems and to remove the users based on demand. PCA technique make this algorithm more efficient by reduce the dimensionality and choose the best possible PC to train the dataset with SVM. The efficiency of the SVM classifier was found to be 90.72% and 94.07% in case of liveness detection, when compared with other algorithm such as Naïve Bayes and Random Forest, SVM produced better accuracy and found to be much more precise. Facial recognition-based applications generally considered as top secure applications but expensive. Today the cost is not real issue because the core technologies have evolved and due to large scale integration and improved processing power the cost of an equipment dramatically going down. As a result, there are no financial constrains between the technology and the user for stepping from small deployment of technology to widespread deployment.

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